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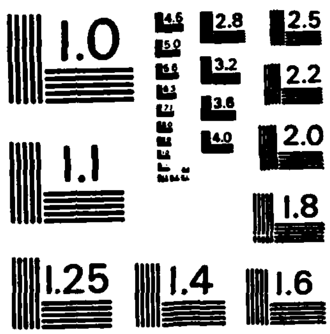

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NORDA Report 22

TEST AND EVALUATION OF CGC POLAR STAR WAGB 10

VOLUME II TEST PLANS

JAMES P. WELSH, JR.

Polar Oceanography Branch
Oceanography Division
Naval Oceanographic Laboratory

September 1978

Prepared for:
Coast Guard Research
and Development Center,
Groton, CT.

Approved for
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NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
NSTL Station, Mississippi 39529

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FOREWORD

CGC POLAR STAR is the first of a new class of American icebreakers built for and operated by the U.S. Coast Guard. The vessel's design incorporates many new and sophisticated systems not found on earlier icebreakers.

The primary objective of the test and evaluation program was to examine the performance characteristics under actual polar operations. Two field trials were conducted. The first in the Arctic (Appendix A) and the second in the Antarctic. During these field trials approximately 120 individual parameters were measured and recorded on magnetic tape (Appendix B). Additionally, the physical properties of the sea ice in which the ship was operating were measured.

Documentation of the complete program including preliminary screening of the data has been accomplished by NORDA under contract to the Coast Guard Research and Development Center. The documentation consists of the following four volumes: I. Antarctic trials, II. Test Plans, III. Background, and IV. Instrumentation Manual.

EXECUTIVE SUMMARY

Section I of this volume provides an overview of the icebreaking performance testing of the POLAR STAR conducted during the months of December, 1977 and January 1978, in Antartica. It should be noted that only a brief period was available for these tests, so the emphasis was on obtaining the most critical data in the least possible time.

Section II is a description of the testing performed by the U.S. Naval Ship Research and Development Center (NSRDC), which was a major fraction of the testing discussed in Section I. Section II also contains a description of the instrumentation installed, and operated by NSRDC to measure the loads on the ship's propellers. This instrumentation was separate from other instrumentation installed and operated by the U.S. Coast Guard Research, (R&DC) and Development Center to measure hull strain, general propulsion machinery performance and icebreaking performance. The R&DC instrumentation is described in detail in Volume IV.

It was orginally planned to test the POLAR STAR for about 8 weeks during the spring of 1976. In anticipation of such an extensive period of testing, a comprehensive test plan was prepared. Because this test period was drastically curtailed due to failure of the outboard propellers the test plan was not utilized. It has been included in this volume as section III, primarily to indicate the testing that would have been performed had the time been available.

Ralph R. Goodman

RALPH R. GOODMAN
TECHNICAL DIRECTOR
NORDA

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A. Overview

The primary purpose of Ice Trials is to determine the loads on the propeller blades and hub internals while the ship is operating in ice. Measuring these loads will allow a determination of the necessity for any operating restrictions in terms of ship's speed through the ice, shaft RPM, and/or pitch. Because of the limited time available to conduct the Ice Trials, a formal, rigid test plan has not been developed. This test plan takes the form of a generalized "game plan" with a high degree of flexibility. The intent is to gather as much data as possible for whatever ice condition is available. Targets of opportunity will be attacked. Ice conditions are expected to be such that initial encounters will be cautious probes, with low ships speeds and power settings. It is desired to be able to quantify the ice characteristics in general terms so that the data gathered will be more meaningful. Data channels for critical components in the shafting system will be monitored on a real time basis. A determination to proceed to more rigorous icebreaking conditions will depend upon the measured loads. Testing will continue until either the loads become unacceptable or time runs out.

B. Location of Ice Trials

Ice Trials will be conducted in the Antarctic regions; first, in the outer pack, then to the inner pack, and finally in the fast annual ice of McMurdo Sound. The goal is to wrap up testing at the completion of the channel break into McMurdo Station. If necessary, time will be available after the channel breakout to allow for additional testing.

C. Test Personnel

Test Director: CDR K. E. Wagner

Dr. J. P. Welsh

LTJG R. M. Mullen

MSTC T. S. Ellis

MST3 E. L. Presher

Mr. N. R. Salassi

DTNSRDC:	Mr. Gary Antonides
	Mr. Adrian Hagen
	Mr. Sam Dawson
	Mr. Alvin Chalk
Photographer:	Assigned to POLAR STAR BY COMDT (G-APA)

D. Discussion

As stated in the Overview. The execution of the Ice Trials will be subjective in nature with no rigid plan of action. It is necessary to proceed in this manner primarily because of the rather limited time available to conduct the tests. This time constraint, coupled with the over riding necessity to determine whether any system operating restrictions will be necessary, require an approach that will allow load measurements for the existing operating programs (SRPM and pitch) first. If time remains after these conditions are evaluated, off program conditions will be evaluated.

The theory indicates that blade loads (bending and spindle turque) while milling ice are increased as the following changes occur:

- Increasing Ship Speed
- Decreasing Shaft RPM
- Decreasing blade pitch angle

Quite obviously these three variables are not independent, i.e., for a given power available, increasing SRPM would require a reduction in pitch, and for a given hull resistance and SRPM, slowing the ships speed of advance would require a reduction in pitch. The interaction between these variables as they affect blade loads is not known. It is hoped that the data collected will allow a determination of these interactions so that the optimum system operating program may be determined.

It is envisioned that the actual conduct of the test would proceed as follows:

Upon arrival at the edge of suitable ice, place two diesels on each shaft and set up IB mode.

Proceed cautiously into the ice at a low pitch setting, say,

handle position 2. Gather data and monitor critical loads.

If unable to make headway, increase the handle position one number at a time until headway is gained. From previous ice operations and ice model testing, the propellers should encounter ice with the ship moving ahead and ice concentrations of 6-8 OCTAS.

With the propellers processing ice, gather data at slow ship speeds and low power levels.

Stop the ship. Analyze the data to determine the loads.

If the measured loads are satisfactory, proceed with the tests using more power and gradually increasing speeds of advance.

The underlying theme is to proceed from the very cautious beginning to the more difficult conditions, stopping along the way to evaluate the loads.

When it is no longer possible to make continuous headway in Diesel Electric Mode at handle position 10, backing and ramming should be attempted.

After backing and ramming several times, and while still in ice that prevents continuous headway with diesels, shift to gas turbine mode on all three shafts. Again, step-wise increase the handle position until slow continuous headway is maintained. Allowing sufficient time for data gathering, continue increasing handle position, thus increasing pitch and ship's speed.

It is envisioned that the helicopters would be used extensively during the trials. They would provide support in three areas. First, in order to search out promising ice condition, they would be utilized for reconnassiance. Secondly, use of the helicopters to move test personnel and/or equipment on the ice is desired. Thirdly, it is envisioned that the helos will be used extensively during the trials as a photography platform, using video tape recording, motion pictures and stills.

E. Collection of Data

During the conduct of Ice Trials, the following types of data will be gathered:

1. Meteorological and Ice Condition Data - Temperature, dew point, barometric, pressure, wind vector, and ice coverage observation will be collected by bridge personnel during each run. Additionally, R&D center personnel will profile the ice depth and char-

acteristics for each set of runs. This data will be gathered by sled tow of a "radar" device to determine ice thickness and temp/salinity information (See H. General Description of Field work).

2. Ship/Machinery Response Data - The Coast Guard R&D Center installed instrumentation will be utilized to record data related to machinery response, ship motion, and hull loading while breaking ice. All data will be recorded on magnetic tape.

3. Propeller Load Data - The DTNSRDC installed instrumentation will be utilized to record ice loading on the controllable pitch propeller blades, trunnion, and links. Additionally, pitch, shaft RPM, shaft torque, etc., will be recorded. All data channels will be recorded on magnetic tape.

F. Evaluation of Data

Because of the prior failures of the controllable pitch propellers in ice, and the discovery of the many gaps in theory of load transfer from ice to the blade, it is necessary that some preconceived load constraints be imposed to insure that the design loads of the modified propellers are not exceeded. The design loads listed below are the result of an extensive mathematical/computer analysis of the blade-ice interaction and resulting loads.

In terms of measureable forces, a link load of 852,453 pounds corresponds to system endurance limit stresses. This link load will produce a stress in the eye area of the link of approximately 107,000 pis, the material endurance limit. The stress at this load at the strain gage location will be as indicated. This link load corresponds to a spindle torque of approximately 12.7×10^6 inch-pounds. The stresses shown for the blade and trunnion are the material (CA6NM) endurance limits and yield point.

Component	Endurance Limit Design May Stress (PSI)	Yield Point (PSI)
Link	21,610	41,000
Blade	28,000	80,000
Trunnion	28,000	80,000

The values will be used to make modified Goodman diagrams. A sample is shown in Figure 1. The measured mean and alternating stresses will be plotted on one of these diagrams. If the point falls beneath the endurance limit-yield point line, the load will be con-

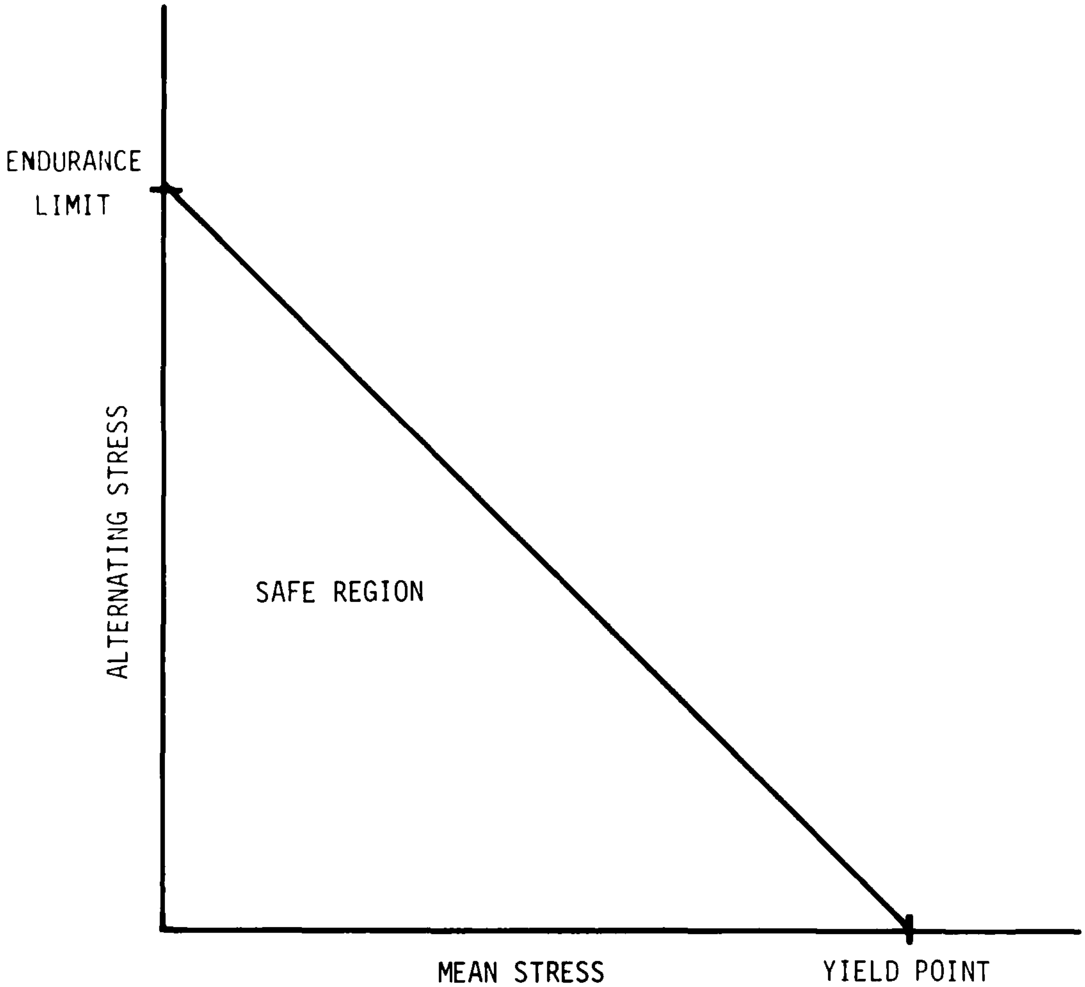


Figure 1. Modified Goodman diagram

sidered acceptable. This method of display permits consideration of both mean and alternating stresses.

During each period of icebreaking one (1) oscillograph will be dedicated to displaying selected critical stresses for real time monitoring. After each run or propeller encounter with ice, these recordings will be scanned for maximum stresses. If these loads are acceptable, the trials will proceed to more severe conditions. As time permits during the trials, all of the recorded stresses will be examined and the results recorded on Goodman diagrams.

G. Possible Actions in the Event Stress Levels Approach or Exceed Allowable Limits

1. Reduce Ship Speed - This is normally accomplished by reducing handle position which reduces pitch. Since the propeller blade loads will probably increase if pitch is reduced (SRPM and ship speed constant), reducing power on the centerline shaft only would seem appropriate. When operating in the less severe ice conditions a feel can be obtained for the approximate increase in loading when pitch is reduced. With this knowledge, an additional factor of safety can be applied to the allowable stresses to allow for a pitch reduction to slow the ship speed.

2. Increase Pitch - If pitch can be increased without increasing ship speed, theory says that the blade loads will be reduced.

Any contingency plan of action will have to be based on the experience gained while operating in the less severe ice condition. This , again, underscores the importance of gathering full and meaningful data during the initial phases of the testing.

H. General Description of Ice Properties Measurements

Two different testing environments are anticipated: (1) individual floes or loose pack, and (2) the bay ice of McMurdo Sound. Each environment will be sampled in a different manner. In general the same ice measurements will be taken in both environments. In priority order they are: (1) ice and snow thickness, (2) freeboard (infer ice field pressure) ice cores for, (3) temperature, (4) salinity, (5) density, and (6) "penetrometer" for inferred compressive strength (Gerard, Third International Symposium on Ice Problems, Hanover, New Hampshire). The temperature and salinity measurements will be used to infer flexural strength.

The loose pack ice environment will be sampled by a small field party of three or four with ice coring equipment and sled transportation. In addition a photographic effort from the helicopter will be made to measure floe sizes. High contrast black and white

film will be used. The photos will be developed on return to the ship.

Concerted effort will be made to obtain a time series of vertical aerial photos with the ship imaged in the central one-tenth of the photo (for scale). The time series would consist of photos taken from, as near as possible, one position at one altitude over one second intervals for as long as is reasonable or at least three photos.

The ice party will obtain at least three samples by a ramdom procedure from each floe within time and safety limits. The random procedure for selecting a sample will be referenced to an arbitrary starting point on the floe and make use of a random number table. Two numbers will be used to locate each sample site. The first number will be a three digit number from 000 to 360 and will determine the horizontal angle from the arbitrary starting point. The second number will be a two digit number from 00 to 99 and will be the number of paces along the previously selected azimuth from the arbitrary starting point to the sample site. The same procedure will be repeated using each occupied sampling site as the new starting point. If either of the random numbers selected provides an unsafe sample position another selection will be made until a safe position is obtained. The core samples will be returned to the ship for salinity and density measurements. Thickness of ice and snow, temperature and freeboard will be recorded while on the ice. The penetrometer technique (ramset) will be used as time permits.

The McMurdo Sound environment will probably provide the best or most consistent ice testing conditions. Two different testing procedures will be used.

The All-Terrain-Vehicles (ATV) will be put on the ice; one will be used with the impulse radar and the other will be used for the coring operations. Thus the two procedures will be essentially (1) a concentrated ice thickness measurement effort and (2) obtaining ice cores for calibration of the impulse radar, temperature, salinity, density and inference of flexural and compressive strength.

An impulse radar (Manufactured by Geophysical Survey Systems, Inc. MA.) will be towed by one ATV with two of the field party aboard. The goal is to obtain, as exhaustive as possible, a complete survey of the ice thickness along and to both sides of the intended ship's track. The individual survey lines will be selected to provide or generate a grid type description of the thickness for the ice sheet. The offset of each individual survey line will be determined on scene but will probably be on the order of 20 meters. The length of each line will be approximately 1000 meters and the total width of survey area will be approximately six characteristic lengths which will be calculated on scene when a representative ice thickness has been obtained. The characteristic length is used as an estimator of the area of ice effected by the ship.

The characteristic length is described by the equation:

$$1_c = \sqrt[4]{\frac{Eh^3}{12\ pwg}}$$

where 1 = characteristic length
h = ice thickness
E = elastic modulus
pw = water density
g = acceleration due to gravity

(Nevel, D.E., 1958, Transactions, Engineering Institute of Canada)

E will be based on brine volume relationships and pw will be obtained from temperature and salinity measurements of sea water at the site.

This sampling procedure is purposeful, i.e. systematic, not random. The results will be used to generate fence diagrams for general description of the thickness of the test ice sheet.

The second test procedure will be organized around a random sampling program to obtain ice cores from the intended test track. Ten coring sites will be selected by reference to a random number table. Ten numbers between 000 and 1000 will be chosen before going on the ice. These numbers will determine the distance in meters or paces from an arbitrary starting point on the ice near the ship and be on a line parallel to or coincident with the intended test track. One ATV with three or four of the remaining field party and ice coring equipment will occupy each of the ten sampling sites.

Analysis is discussed in volume I. In general, histograms for each variable will be drawn and of course profiles of the temperature, salinity and density with depth will be drawn.

Much of the above is subject to change as is the situation with all field work, however, it serves as a general outline of what can be anticipated at this time.

II. TEST PLAN FOR UNDERWAY PROPELLER STRESS TRIALS ON USCGC POLAR STAR (WAGB-10)

A. Background

Two new icebreakers, the POLAR class, were recently built for the Coast Guard. They have 3 propellers, each powered by a 20,000 HP gas turbine for ice operations or by a 6,000 HP diesel-electric drive. The propellers are Esher-Wyss designed 4-bladed controllable pitch built by Allis-Chalmers.

In June 1976 the POLAR STAR was operating in ice for the first time. Failures occurred in the pitch changing mechanism of both outboard propellers. The ship returned to port (Seattle) on its centerline propeller. Examination of the propellers showed that the links between the hydraulic piston and the blade adjusting crank had failed. The steel in the links was found to have about half the yield strength specified, and the fit and assembly of the bearings in the links were questionable.

At present Allis-Chalmers is rebuilding all the POLAR Class propellers, increasing the strength of the internal components as much as possible in the present hub. Additionally, DTNSRDC has installed strain gages on the blades and links to make underway measurements starting in late October 1977.

B. Objectives

The primary objective of the underway propeller stress trials on the POLAR STAR is to determine the bending and torsional loads on the propeller blades and the resulting stresses in the blades and the links. These quantities will be determined for operation in open water and in different types of ice. The loads and stresses will be studied as functions of RPM, pitch, rudder angle, and acceleration/deceleration.

The results will be used to evaluate the structural adequacy of the POLAR class propellers and to study the loads on the propellers while operating in ice for future design purposes.

C. Instrumentation

1. Gage Locations - In order to determine the loads on the propeller blades, strain gages have been located in several places on two blades of each outboard propeller. Three rosettes have been placed on the 43" radius as shown in Figure 2. These will respond to both the bending and torsional loads on the blade. In addition, bending and torsional strain gage bridges have been installed in the trunnion area, also shown in Figure 2.

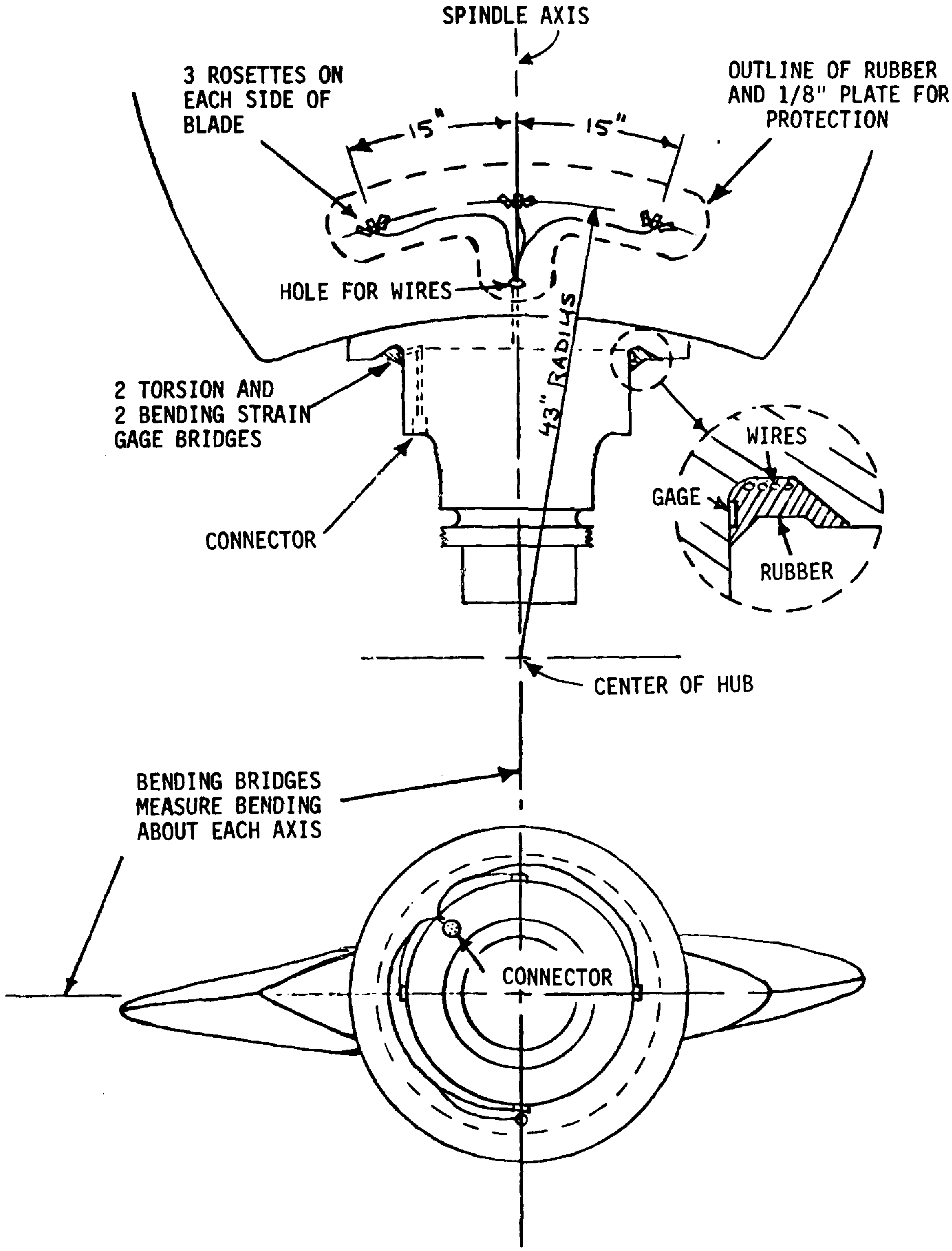


FIGURE 2 LOCATIONS OF STRAIN GAGES ON PROPELLER BLADES

The torsional loads on the blades result in tension or compression on the internal links, which is what caused the propellers to fail. Two bridges have been installed on each of the four links of each outboard prop to measure tension in the center of the link as shown in Figure 3. Two bridges are used here because of the importance of this quantity. In addition, the bending of the links will be measured by two bridges oriented 90° from each other. Normally there will be negligible bending in the links; but if there are bearing problems such as occurred before, the bending stresses will serve as a warning.

In addition to stresses in the blades and links, the following quantities will be measured:

- RPM of all 3 shafts. A once per rev signal will be superimposed on a multiple pulse signal. The latter will indicate any slowing of the prop due to ice impact.

- Pitch of each propeller. The ship's indicator will be used for all three props. In addition, DTNSRDC indicators will be installed on the instrumented (outboard) props.

- Rudder angle. This will be recorded from the ship's existing instrumentation.

- Shaft thrust of all three shafts. Three thrust shoes from each shaft are instrumented already and these signals will be recorded.

- Shaft torque on all three shafts. Signals will be taken from existing torquemeters.

2. Signal Transmission - The wires from the strain gages on the blades and links pass inside hoses to provide flexible connections to terminal boxes attached to the crossheads as shown in Figure 4. From the terminal boxes, rigid conduit is installed through the hub body and on the outside of the oil tube. At the forward end of the tailshaft a flexible hose section will allow for the relative motion between the oil tube and shaft as shown in Figure 5. The wires come out of the shaft through a locking pin hole and are attached to a telemetering system mounted outside the shaft.

Each telemetering system (one on each outboard shaft) transmits 64 channels of multiplexed information. Power supplies and strain gage bridge completion and balance networks are also mounted on the shaft. A schematic of the on-shaft electronics is shown in Figure 6. The gain of the on-shaft system can be changed by inserting cards with various size resistors on them.

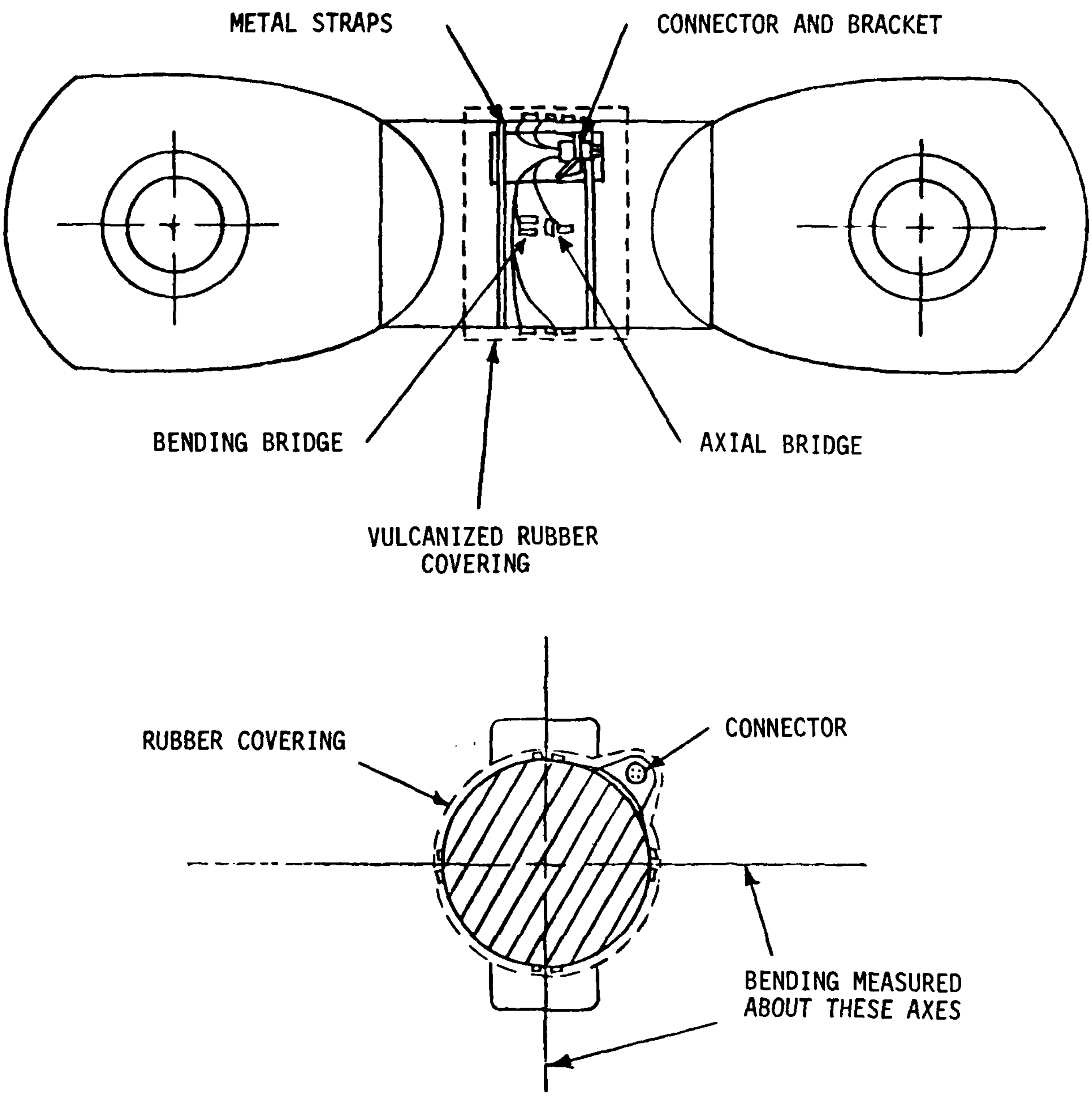


FIGURE 3. LOCATIONS OF STRAIN GAGES ON LINKS

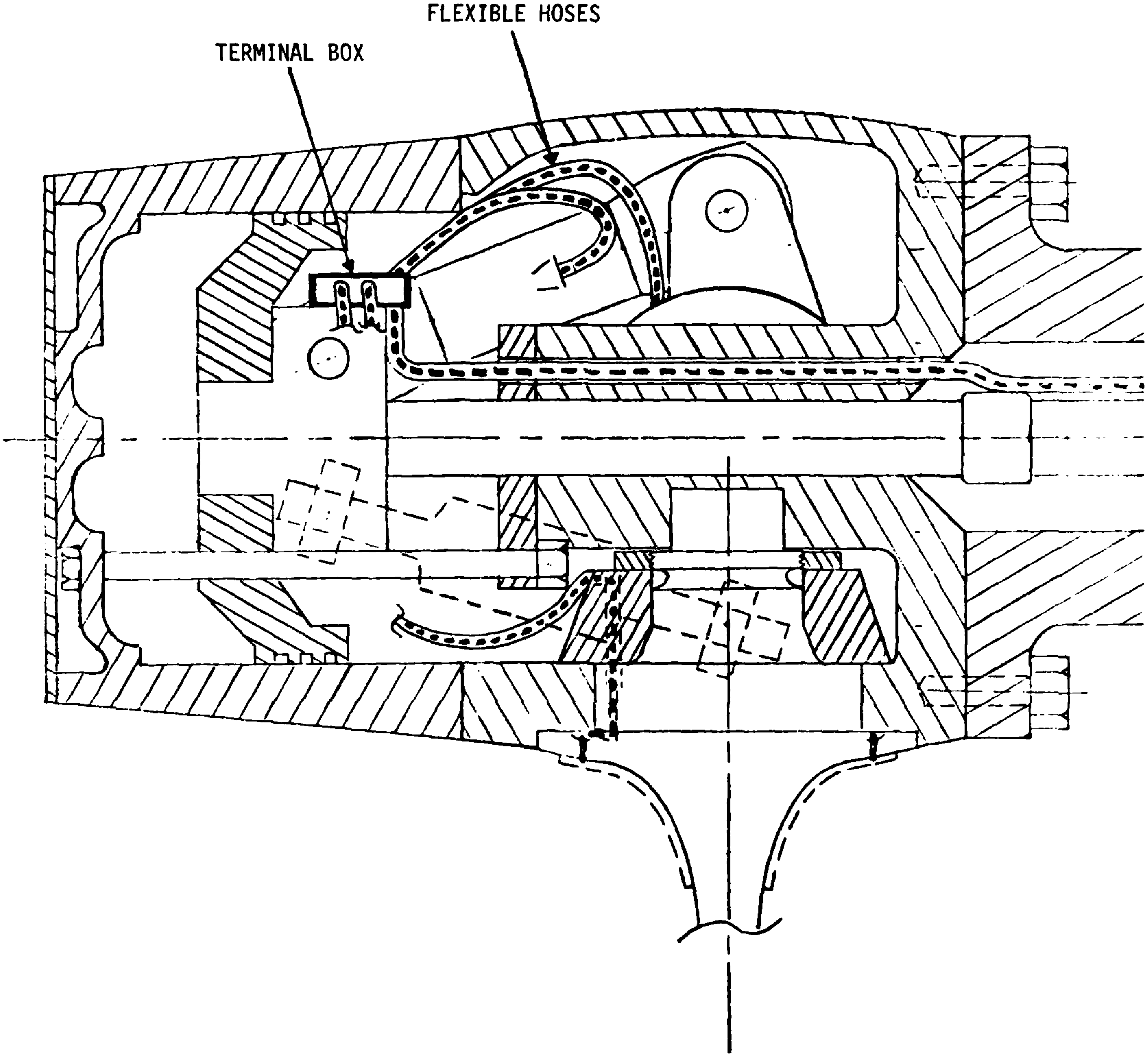


FIGURE 4. SIGNAL CABLE ROUTING IN HUB

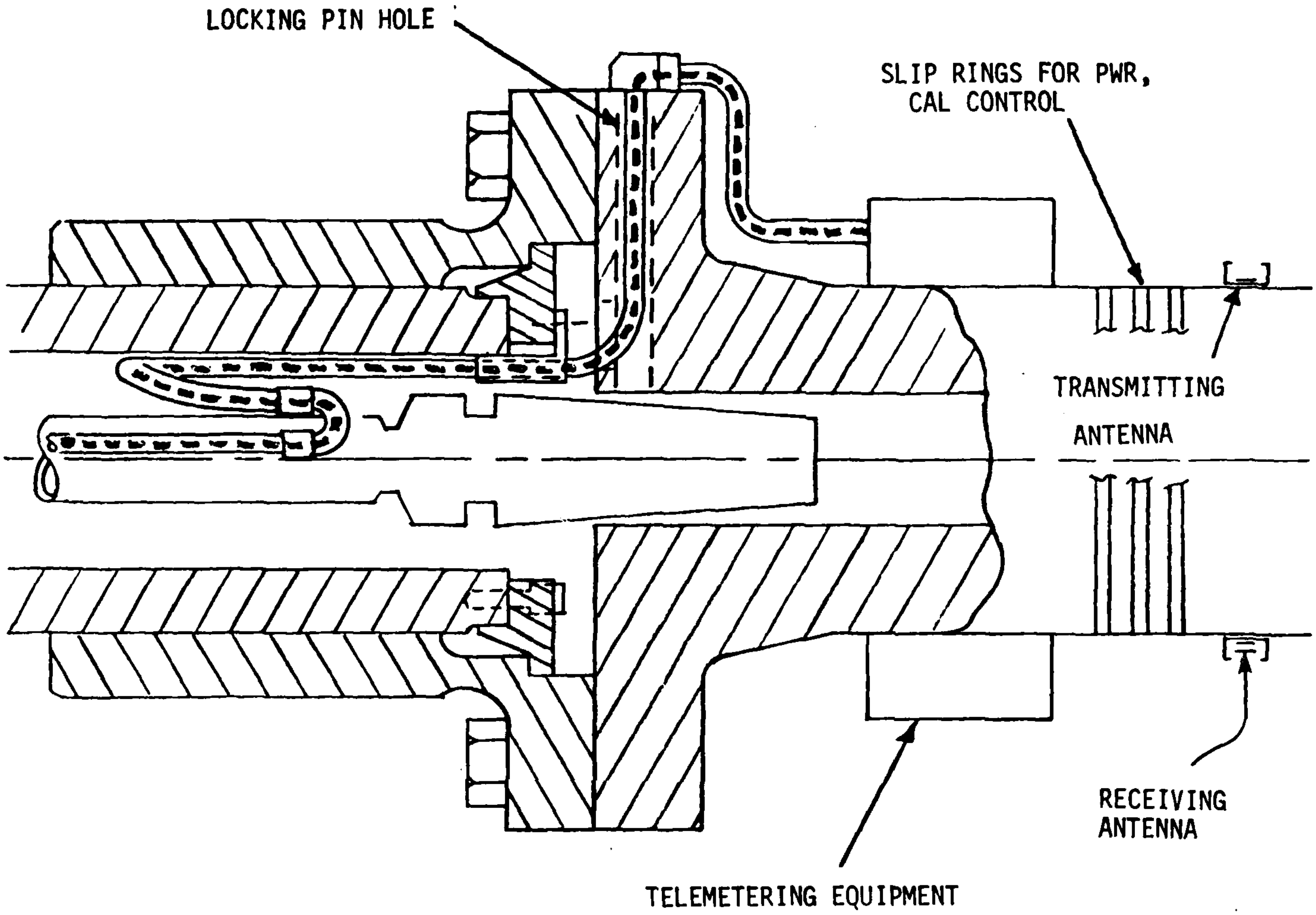


FIGURE 5. SIGNAL CABLE ROUTING IN SHAFT INBOARD

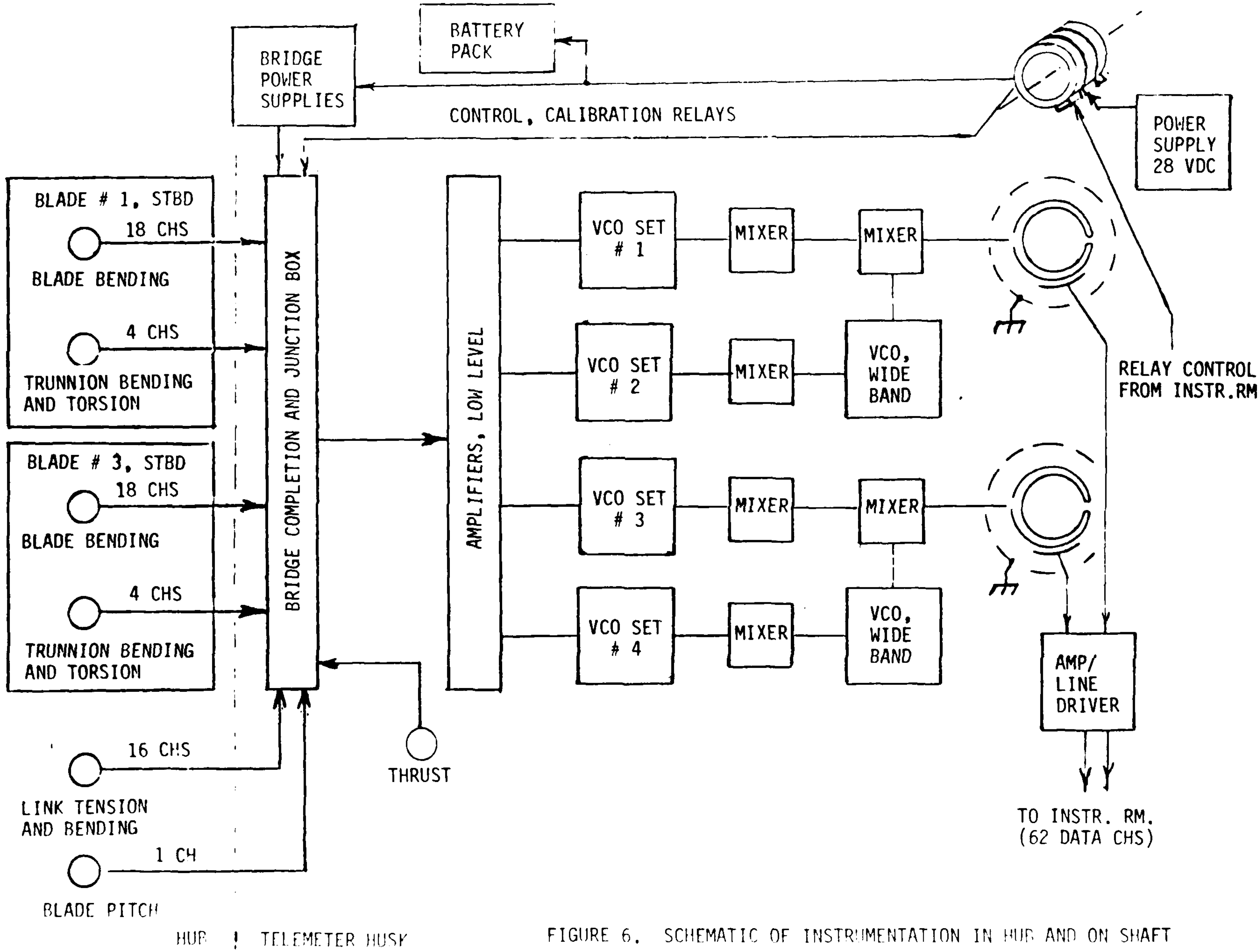


FIGURE 6. SCHEMATIC OF INSTRUMENTATION IN HUB AND ON SHAFT

3. Trial Room - From the receivers the signals go to the trial room. The recording system is shown schematically in Figure 7, and the layout of the trial room is shown in Fiqure 8. All channels are recorded on tape in their multiplexed form. Also, some channels are demultiplexed on line for continuous monitoring and recording on an oscillograph. These are the link bending stresses, RPM, pitch, rudder angle, and about 14 other channels that reflect the highest stressed points in the propeller. These will be selected after the drydock tests.

The trial room has been constructed on the upper level of the motor room and is enclosed and insulated for sound. Fans will be used to ventilate the room and carry away the heat generated by the equipment.

D. Test Conditions

1. Drydock - After the instrumented propellers, telemetering equipment and recording equipment are installed, DTNSRDC will conduct drydock tests. This will involve applying up to 63,000 lbs. to individual blades with DTNSRDC'S blade loader as shown in Fiqure 9. The blade loader has nine hydraulic rams supplied by a single hydraulic pump, but with individual cut off valves. Each ram is strain gaged to accurately determine the load.

On each instrumented blade the following loads will be applied:

- 3 rams at .7 radius, 7,000 lbs/ram
- 3 rams at .8 radius, 7,000 lbs/ram
- 3 rams at .9 radius, 7,000 lbs/ram
- 3 rams nearest leading edge, 7,000 lbs/ram
- 3 rams on spindle axis, 7,000 lbs/ram
- 3 rams nearest trailing edge, 7,000 lbs/ram
- All 9 rams, 1000 to 7,000 lbs/ram in 1000 lb steps.

Data will be taken on the blade and links which are loaded. The blade loads in drydock are well defined, but the loads on the links are affected by friction in the system. Therefore the links will be calibrated by loading at DRNSRDC prior to installing in the hub.

In addition, the major natural frequencies of the blades will be determined by striking a blade with a large hammer and measuring the

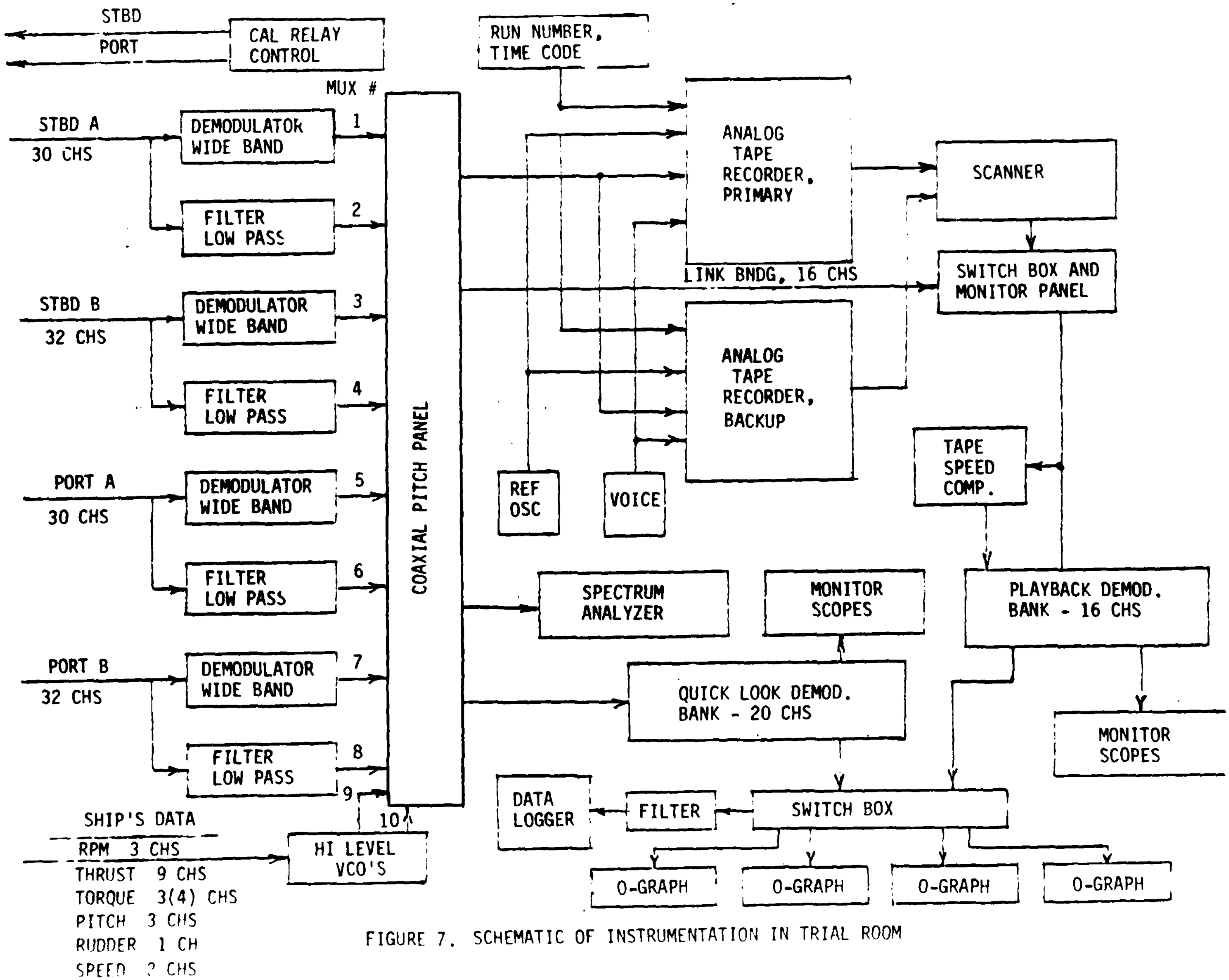


FIGURE 7. SCHEMATIC OF INSTRUMENTATION IN TRIAL ROOM

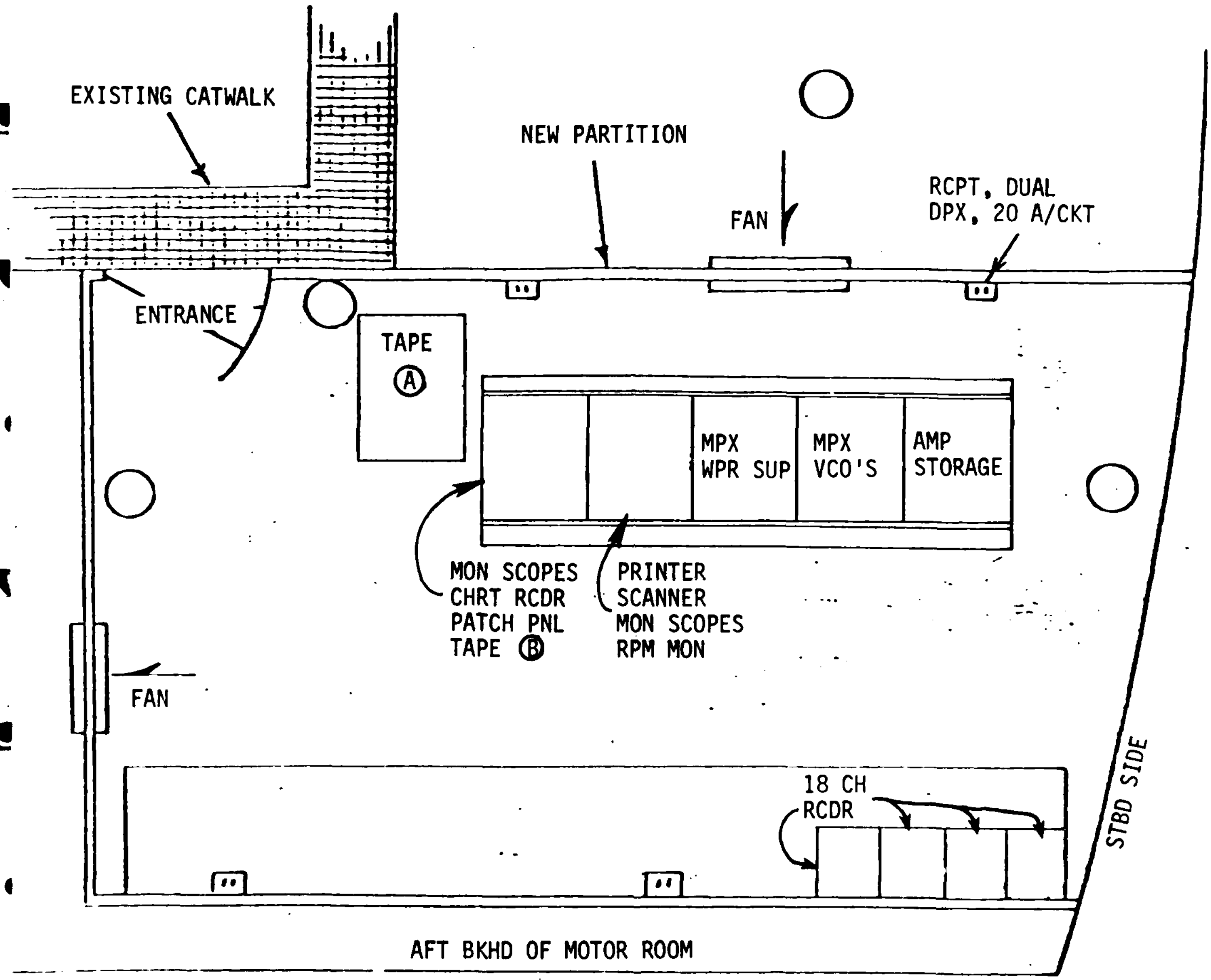


FIGURE 8. LAYOUT OF TRIAL ROOM

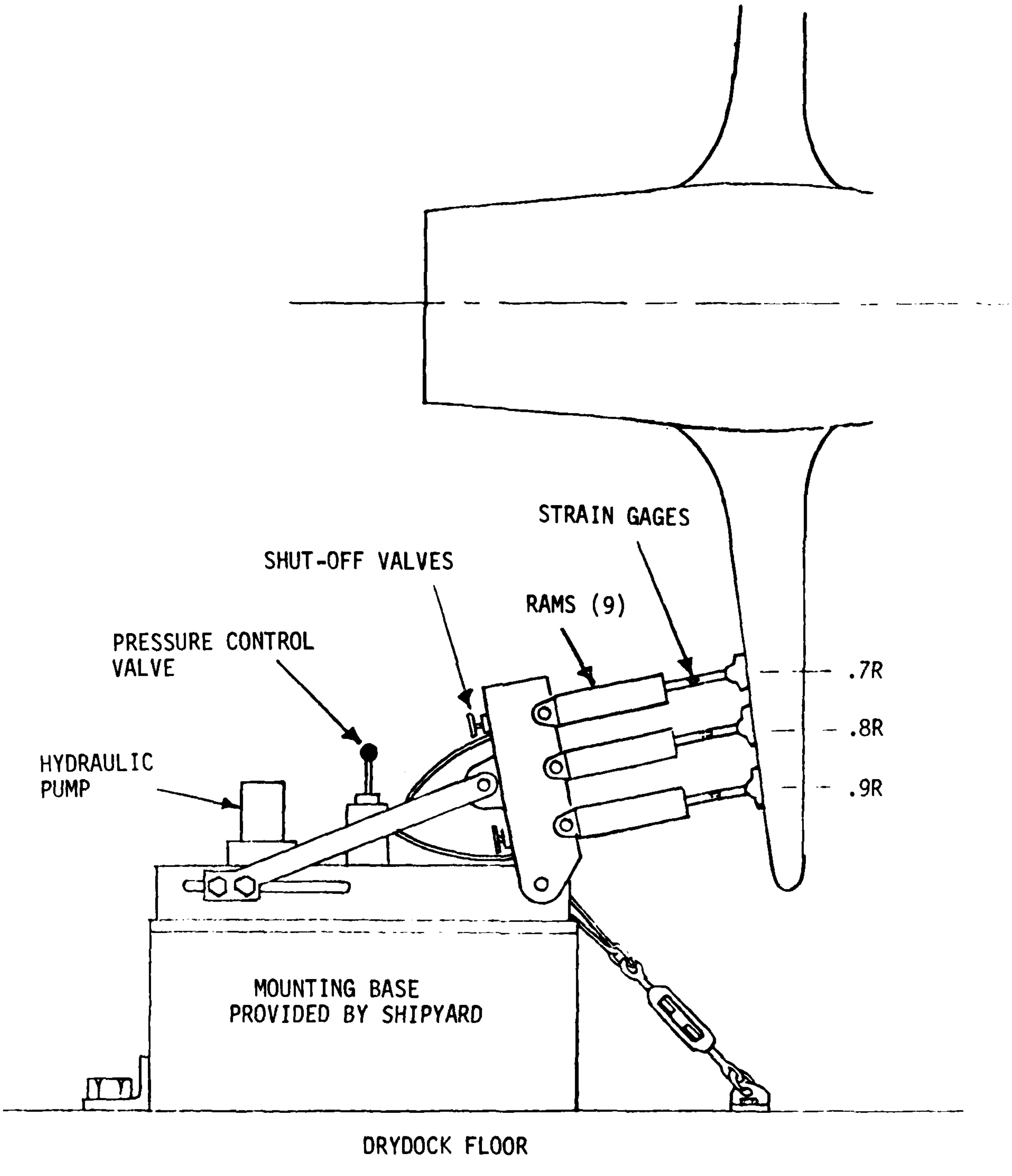


FIGURE 9. DTNSRDC PROPELLER BLADE LOADER

transient response with an accelerometer temporarily attached to the blade.

2. Dockside - After the dock is flooded, divers will determine the natural frequencies again by the same method as during the drydock tests.

3. Underway in Open Water - As soon as is practical after undocking, trials will be run on the Naval Torpedo Station range in Dabob Bay. Mean and alternating stresses will be measured for various RPM, pitch settings, and rudder angle. Crashbacks (decelerations) and crashaheads (accelerations) will be studied. DTNSRDC has given USCG HQ detailed recommendations for the open water trials. These were discussed and combined with the ship's tactical data requirements at a conference at NTS on 25 Aug. NTS will issue a Run Plan as agreed to at that conference.

4. Underway in Ice - The test conditions for ice operations have not yet been determined.

III FINAL TEST PLAN FOR THE USCGC POLAR STAR ICE TRIALS

A. Introduction

This test plan has been prepared in support of the testing and evaluation of the USCGC POLAR STAR (WAGB-10). Since the time of the writing of the plan, there has been a delay in the delivery of the ship by the builder. This will result in necessary changes to the testing program; however, the plan has established priorities for the tests and has made allowance for changes required by the actual ice conditions. Because the tests will be later in the year, the ship will undoubtedly have to go further north into the Chukchi Sea and Beaufort Sea.

The preparation of the plan was a cooperative effort of the U. S. Coast Guard and ARCTEC, Incorporated. The coauthors are:

E. J. Lecourt, ARCTEC, Incorporated
LCDR James A. McIntosh, USCG Research & Development Center
Dr. J. P. Welsh, Jr., USCG Research & Development Center

Contributions were also made by:

LCDR John N. Naegle, Naval Engineering Division
LCDR Hugh L. Thomas, Naval Engineering Division
CDR George P. Vance, U.S. Coast Guard Academy

CAPT Norman C. Venzke and the officers and crew of the POLAR STAR were helpful in their review of the test plan.

B. Objectives

The objectives of the USCGC POLAR STAR ice trials are fourfold:

1. To determine the POLAR STAR's operating characteristics in ice which will assist future Commanding Officers, Officers, and Crews in understanding the capabilities and limitations of the ship on an objective basis.

2. To record operating data on the ship's propulsion system to aid in the evaluation of the system design and to provide information which will be useful in analyzing future machinery problems.

3. To develop objective design criteria for the interaction of an icebreaker hull, propeller, and rudder with ice.

4. To advance the general state-of-the-art of icebreaking technology.

C. Number of Test Days Expected

POLAR STAR is currently planned to depart Seattle, Washington in early January 1976, and return about mid April 1976. Assuming that one week is required for the open water voyage leg between Seattle and Unimak Pass, operations in the Bering and Chukchi Seas will encompass the period late January through March.

Eight weeks of testing north of Unimak Pass can be planned. Analysis of environmental conditions in the area and past experience from full-scale testing of the STATEN ISLAND would indicate that a maximum of three days of testing can be expected per week. The remaining four days reflect time for transit between test areas; time consumed looking for desirable test areas; time lost due to snow storms, pressure in ice field and the other environmental factors; time lost due to test equipment malfunction; time lost due to possible propulsion machinery malfunction; and time for other ship operations. In general, therefore, the total number of test days expected is:

$$3\ \frac{\text{days}}{\text{week}} \times 8\ \text{weeks} = 24\ \text{test days}$$

Assuming the tests in any given areas can be performed in a 3-day period, eight different test sites may be the maximum available for testing. However, it should not be assumed that, if twenty-four days of testing have been completed before the scheduled termination date, the ship will terminate the test program early. A thorough exploration of the tests outlined in this plan would require more time than will be available.

D. Possible Test Sites and Ice Reconnaissance

With test objectives requiring testing in level ice from one to six feet and in pressure ridges of up to 20-foot keel depth, sites have been tentatively selected where these ice conditions may be found, based on a typical ice year. Naturally, actual site location will be based on the prevailing ice conditions at the time.

In general, however, Figure 10 and Table 1 describe possible test sites. It should be emphasized that large areas of uniformly thick ice are not commonly found in the Bering Sea and Chukchi Sea. Much time will be devoted to ice reconnaissance. As Figure 10 shows, most of the preliminary test sites are based on locations which are leeward of islands and in the proximity of inlets or sounds. Unfortunately, many of the inlets and sounds have water depths of 60 feet or less (as shown on Figure 11) thus precluding testing in several otherwise suitable areas.

An aerial survey of the Bering Sea and the southern Chukchi Sea by an aircraft equipped with a side-looking airborne radar is planned for the period approximately 10 days before the ship enters the ice. The results of this survey will be used, together with information gathered from other sources, such as satellite imagery and fleet weather facility, to select the areas in which tests will be conducted and to decide upon the order in which the sites will be visited. It is anticipated that the ship's helicopters will then be used extensively to select the particular floes within an area to be used for the tests. The tracklines selected for the SLAR aircraft are shown in Figure 12. R&DC personnel (not those scheduled to be on the ship) will operate the radar, develop the resulting films, and prepare charts showing the observed ice conditions at various locations. The information obtained during this initial survey will be passed to the ship by having a helicopter from the ship rendezvous with the SLAR aircraft at the Cape Sarichef airstrip.

Additional SLAR reconnaissance flights will be flown during the test period to the extent that funds, aircraft flight time and SLAR-qualified personnel are available, one flight every third day

Table 1

POSSIBLE TEST SITES AND TYPE OF ICE TO BE ENCOUNTERED

Test Site	Location	Ice Characteristics Type	Thickness
1	St. Matthews Island	1st year ice/ Pressure Ridges	1-2 ft.
2	St. Lawrence Island	Pressure ridges	2-3 ft.
3	East of St. Lawrence Island	Pressure ridges	2-3 ft.
4	North of St. Lawrence Island	1st year ice	3-4 ft.
5	Kotzebue Sound	Multi-year floes	4-5 ft.
6	Port Clarence	Grounded pressure ridges/1st year ice	3-4 ft.
7	Norton Sound	1st year ice	3-4 ft.
8	Bristol Bay	1st year ice	1 ft.

Figure 10

POSSIBLE SITES FOR ICEBREAKING TEST PROGRAM

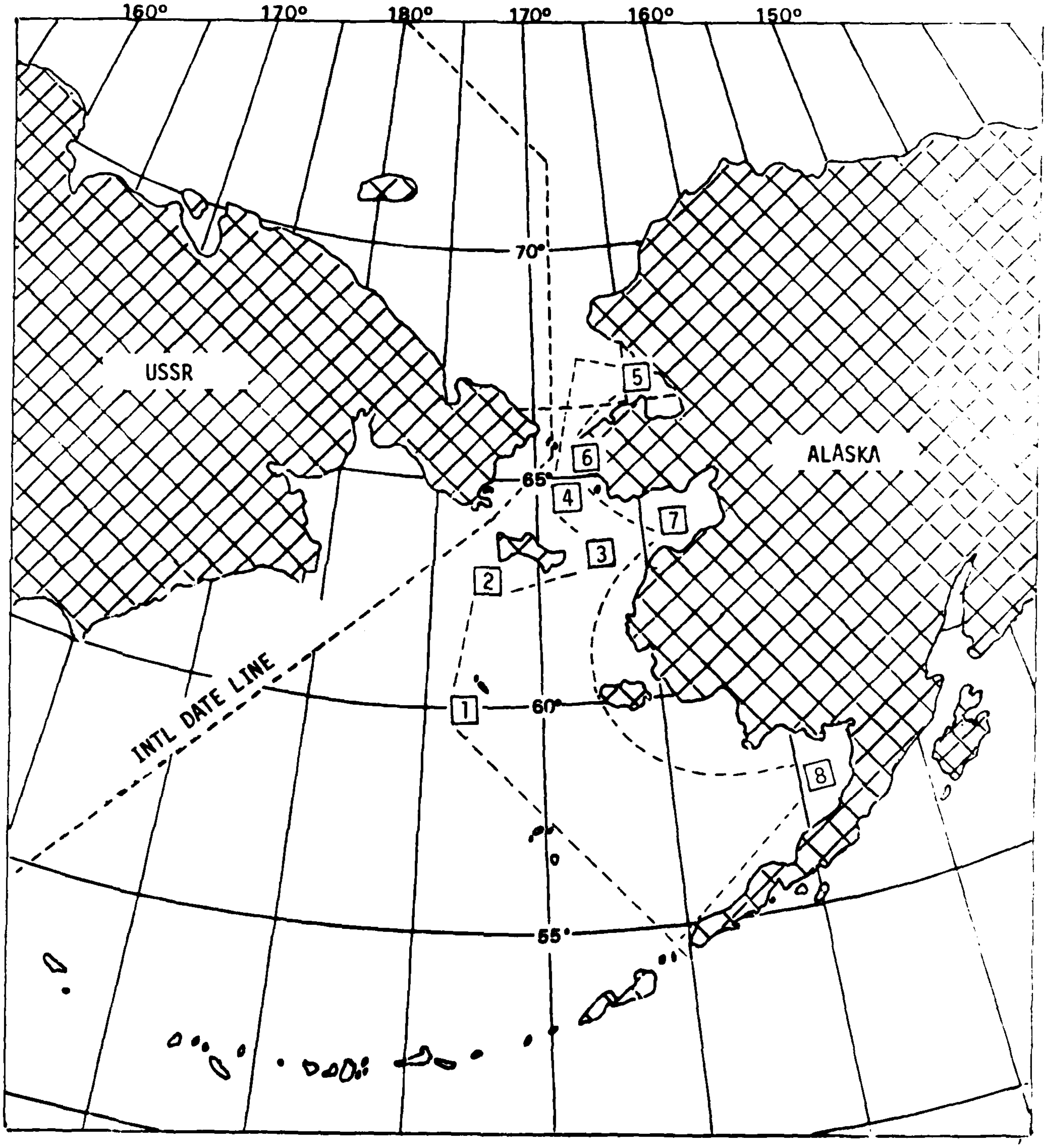
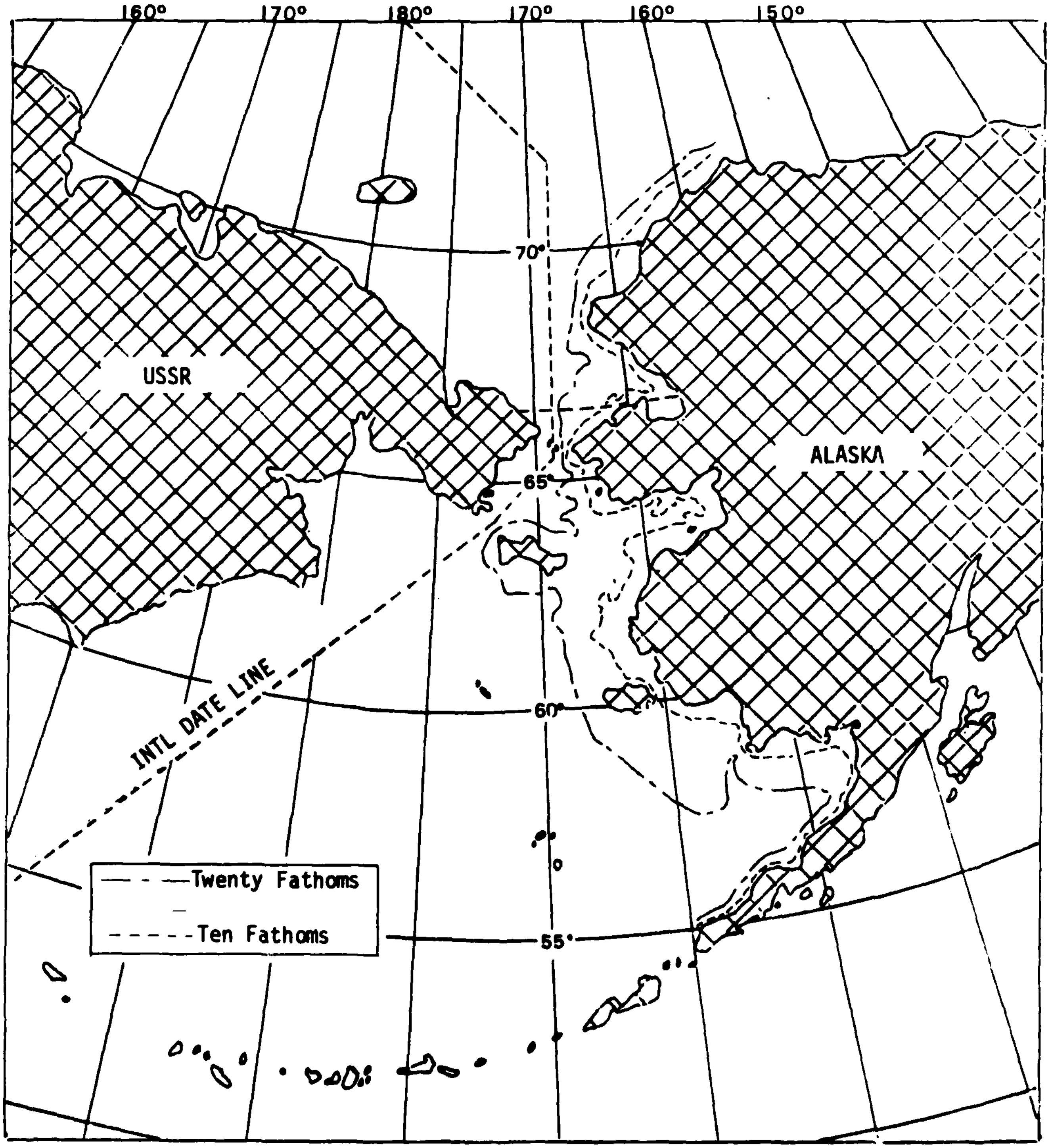


Figure 11

WATER DEPTH CONTOURS



will be the nominal schedule, subject to demand, not to exceed 45 days total time. SLAR data obtained when the ship is no longer within helicopter range of an airstrip suitable for the SLAR aircraft will be air-dropped to the ship by the SLAR aircraft.

E. Scenario of Typical Test Day

The ship has found a large floe and is hove to in it, preparing for a day of testing. As shown in Table 2 , a number of activities are planned.

If the weather permits, both helicopters will be launched at about 0830, with an ice observer aboard one of them to search for and select the floe for use after the tests in the present one are completed. If aerial photography is required of the test that is scheduled, the second helicopter will return in time to embark a photographer. The helicopters would be recovered starting at about 1100. The ship will maneuver as necessary, but as little as necessary, to safely launch and recover the helicopters.

Other than the ice observers, five teams will be required for routine work on the ice. These are: (1) the Ice Thickness Team, consisting of two men (R&DC personnel) who will operate the ice thickness radar; (2) the Flag Team, consisting of two men (POLAR STAR personnel) who will place speed measurement flags at measured distances; (3) the Ice Core Team, consisting of four men (R&DC personnel) who will obtain ice temperatures, salinity and density data and obtain wind velocity and air temperature data; (4) the Ice Friction Team, consisting of six men (one R&DC, five POLAR STAR) who will set up, operate and strike down the ice/hull friction measurement equipment; (5) the Flag Observing Team, consisting of two men (POLAR STAR personnel) to observe and mark the passing of flags from positions on the vessel. In order to provide for sufficient job expertise, consistent data, safety of personnel and proper organizational control, it is expected that individuals would be assigned to a particular team and would remain with that team for the whole cruise. Also, if conditions permit, the first three teams would lunch on the ice; doing so would increase the productive time available and would be more comfortable for the team members. Otherwise, they will lunch aboard ship.

For most of the tests the ship would be underway for data collection purposes for 30-45 minutes at about 1000 and at about 1400, weather permitting (wind in excess of 20 knots, for example, would probably cause postponement). While the ship is underway, two photographers and the Flag Observing Team will be required. One of the two photographers will operate a still camera, the other a motion picture camera; one or both may be in a helicopter, on the

Figure 12

TRACKLINES SELECTED FOR THE SLAR AIRCRAFT.

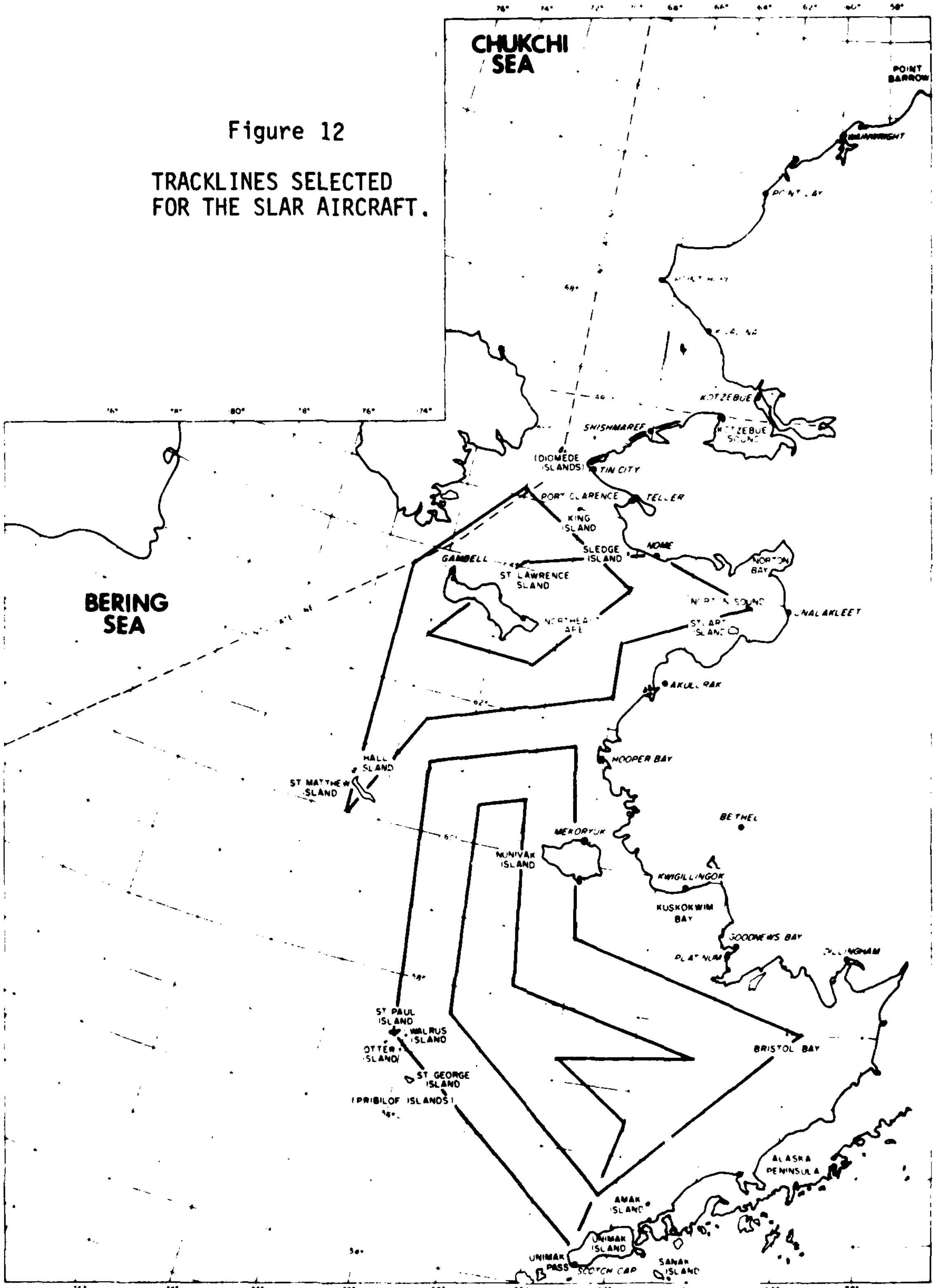


Table 2.

PROPOSED TYPICAL TEAM/ACTIVITY SCHEDULE

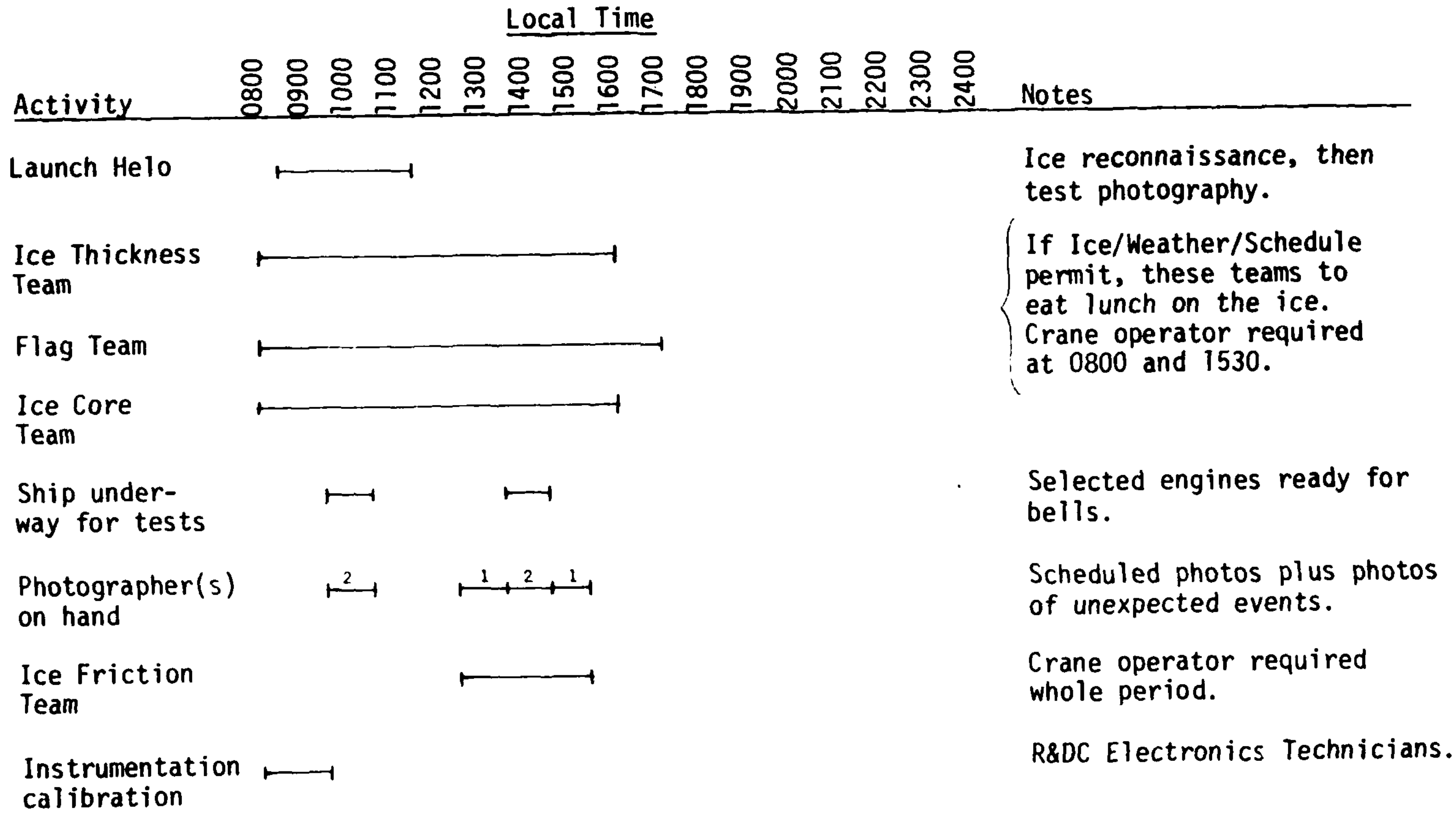
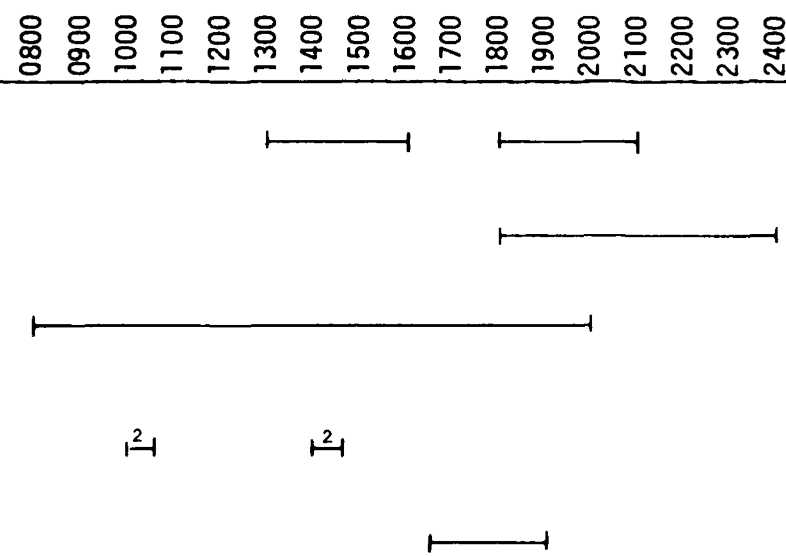


Table 2, (Continued)

PROPOSED TYPICAL TEAM/ACTIVITY SCHEDULE

Local Time



Activity	Notes
Data Reduction Team	Ship plus R&DC professional personnel.
Computer Operator	Ships measurement or electrical technician.
Instrument Center Operator	R&DC electrical technician.
Flag Observers	Ship's personnel - visual speed measurement.
Ship underway to next floe.	Ship moves when dictated by ice conditions or thickness needed.

ice or on the ship during the test, depending on the need for particular coverage. The Flag Observing Team will be stationed at special sights installed at the bow and stern and would operate a switch whenever a flag (placed on the ice by the Flag Team) passes through their sights. (These switch closures yield ship's speed and the location of the ship within the floe.)

R&DC electronics technicians will be adjusting, calibrating, repairing and operating the recording instrumentation from 0800 to 2000.

Initial raw data will be available for examination at 1230, with additional data available periodically until about 2000. The Data Reduction Team, consisting of from 2 to 4 members, will examine the chart recordings, measure certain portions and transcribe the results onto "first level" worksheets. This work will require the attention of only one or two men at any one time; however, it will be quite tedious and boring. So, four members would permit a rotation of the duty and tend to improve individual levels of performance. As the first level worksheets are completed, the information contained on them will be re-entered onto second-level worksheets to permit convenient computation of the summary data needed to evaluate the test run.

Some of the second-level data sheets will be passed to the computer operator, who will type the data into a PDP-8/S (to be supplied by R&DC) or DDP-516 (ship's equipment) computer. (The computer will be used for certain calculations that are especially tedious or lengthy or both.)

As this effort nears completion, the Test Director will meet with the Operations Officer, MSO and other applicable department heads to evaluate the day's activities and plan procedures for the next day. After verifying operational feasibility, the Operations Officer and Test Director will present a recommended schedule to the Commanding Officer via the Executive Officer. The Test Director will submit all recommendations and requests concerning vessel movement or personnel coordination through the Operations Officer.

Depending on the situation, the Test Director will recommend that the ship move to another nearby floe after all data has been obtained at the present location of the ship; or after examining all available reconnaissance information (SLAR, Satellite imagery, helo observations, Fleet Weather, central forecasts, etc.), he may recommend that the ship move to a different test area entirely. This recommendation will be influenced by many factors, including the number and types of tests completed to date, the time remaining in the test period, the trend of the weather, etc.

F. Scenario of Typical Test Day for Ice Team Personnel

The ice party consists of four teams, not including photographers. The ship has located the desired test ice. The Chief Scientist, after consultation with the Operations Officer and Test Director, selects the starting point or points for intended track lines. The first team over the side is the Flag Team. The Flag Team consists of two men and one sled containing flags and ice thickness equipment. They place the first flag at the selected starting point and record an ice thickness measurement. One ATV with the impulse radar is put on the ice. The ATV with two men is the Ice Thickness Team. They set up the automatic weather station, the mini-ranger and the impulse radar. When the radar is operational, they proceed along the proposed test track. Meanwhile, the flag team will continue to deploy flags at the predetermined spacing, but not making thickness measurements, along the proposed test track. When the end of the proposed test track is reached, the Flag Team will place a flag, and make and record an ice thickness measurement. The Flag Team will provide both ice thickness measurements to the Ice Thickness Team to calibrate the radar. The Ice Thickness Team should complete the test track before the Flag Team does. When both teams have completed the first test track, they will move away from the test area and radio the bridge when they are in a safe position on the ice, at least 100 yards from the proposed test track. When notified by both test teams that they are at a safe distance and on secure ice, the Test Director will request that the Operations Officer begin the test run. After the run is completed, the second ATV with the Ice Core Team will be put on the ice. The Flag Team will recover as many flags as they can in a safe manner and proceed to the starting point of the second test track if the ice is adequate. Meanwhile, the Ice Core Team will proceed along the already used test track obtaining cores, and temperature and density measurements. The Ice Thickness Team will assist by leap-frogging with the Ice Core Team while enroute to the second proposed track line. The Ice Core Team will move the automatic weather station if necessary for safety. In this way wasted effort will be minimized. If, for example, the ice floe were split by the ship on the first run, it might not be feasible to perform a second run and the ice party would have obtained ice data for runs the ship could not make. The above three ice teams will eat lunch on the ice from 1130 to 1200 if adequate ice is available for multiple runs. The fourth ice team, the Friction Ice Team, will deploy with the assistance of a crane operator after lunch or between test runs in the afternoon. They will position the friction test apparatus on the side of the ship and obtain samples of ice from nearby. The samples will be prepared and the friction tests conducted under the direction of the ARCTEC representative with permission from the Commanding Officer and cognizance of the Test Director. The Chief Scientist may

assist as necessary with friction testing. When ice property measurements have been completed for the day's test runs, the ice teams will return to ship. The time should be around 1600. The Flag Team will repair and replenish their equipment and secure for the day. The Ice Core and Ice Thickness Teams will remove ice samples to the laboratory for salinity measurements. While the samples are melting, they will repair and replenish their equipment and secure it and the ATV's for the day. The Ice Thickness Team will reduce the radar data in the science office while the Ice Core Team measures salinities of the collected ice samples. Both teams will then assemble in the science office to prepare the data for transcription onto the second-level data forms. The ice teams will break for dinner around 1700 and return to the science office around 1730. They will continue data reduction until 2030 at which time they will secure for the day.

The work day for the Flag Team will begin at 0800 and end by 1700. The Ice Thickness and Ice Core Teams will begin at 0730 and end at 2030. The Ice Friction Team will begin at 1300 and end at 1600.

G. Test Priorities

Given that there will not be enough time or enough suitable ice to perform all of the desired testing, the Test Director will be guided in forming his recommendations to the Commanding Officer by the test type priority list in Table 3, by the difficulty and/or risk in performing a particular test, by the types and amount of testing completed to date, the test time remaining, and by the trend of the weather, especially the average daily temperature. The general strategy will be to attempt to do a thorough job on the higher priority tests and successively less thorough on the lower priority tests; "thorough" being defined in this instance as sufficient data point replications to bring the confidence level to at least 70%. The numbers of "data points desired" mentioned for each test type in Section II indicate the number of points estimated to be the minimum necessary to adequately characterize the ship's performance for that particular test. Generally, when the "desired" number of points have been obtained for a given test type (not counting replications), a test of lower priority will be performed.

Table 3.

PRIORITY LIST OF TESTS

Priority	Test	Included Tests	Ice Conditions Required	Desired No. of Data Points
1.	C-5 Measured Mile Sensor Calibration	None	Open water.	14
2.	C-1a Crash Reversal	None	Open water.	9
3.	A-1a Continuous Ice-breaking	B1, B2, C1, C2, C3 Ice Impact Forces and Machinery Performance.	Well-supported, level floe or refrozen lead, at least 1/4 mile long; various thicknesses.	50
4.	A-1b Static Resistance	None	Well-supported, level floe or refrozen lead, minimum 200 yards long, various thicknesses.	12
5.	A-2a Ramming - Level Ice	Same as A-1a.	Well-supported, level floe, 3 feet or more thick, 1/4 mile long.	10
6.	A-2a Ramming - Pressure Ridge	Same as A-1a.	Pressure ridges, various sizes, with 1/4 mile of ice on crash side, and 1/4 mile long.	15

(Cont'd)

Table 3. (Continued)

PRIORITY LIST OF TESTS

Priority	Test	Included Tests	Ice Conditions Required	Desired No. of Data Points
7.	A-1c Heeling System during Continuous Icebreaking	Same as A-1a.	Well-supported, level floe or refrozen lead, minimum 1/2 mile long, various thicknesses.	5
8.	A-3 Maneuvering - Turning Circle	Same as A-1a.	Well-supported, level floe, minimum 1 mile square, various thicknesses.	12
9.	C-2 Propeller Ice Impact and Ice Milling	C-1 and C-3 Machinery Performance.	Not critical.	N.A.
10.	B-2 Rudder Ice Impact	None	Not critical.	N.A.
11.	A-4 Hull - Ice Friction	None	Not critical - included with other tests - vessel hove to.	50
12.	A-1d Clogged Channel Resistance	Same as A-1a.	Previously broken channel.	5

H. Test procedures

In order to accomplish the objectives, the test plan has been divided into the following five sections:

Section A. Icebreaking Performance

Section B. Ice Impact Forces

Section C. Machinery Performance

Section D. Environmental Data Collection

Section E. Photographic Documentation

These sections are further subdivided and numbered as shown in Figure 13. This numbering system will be utilized throughout the planning, testing, analysis, and report writing phases of the program.

Descriptions of each test, the instrumentation required, procedures to be followed, and personnel required are included in the following pages. The specific procedures to be followed for each test will be modified in the field to suit the existing conditions and to benefit from past experience.

Shipboard personnel assigned to projects on the ice will be briefed completely on their duties and the safety procedures to be observed in using their equipment and on the special precautions required while on the ice due to the tests.

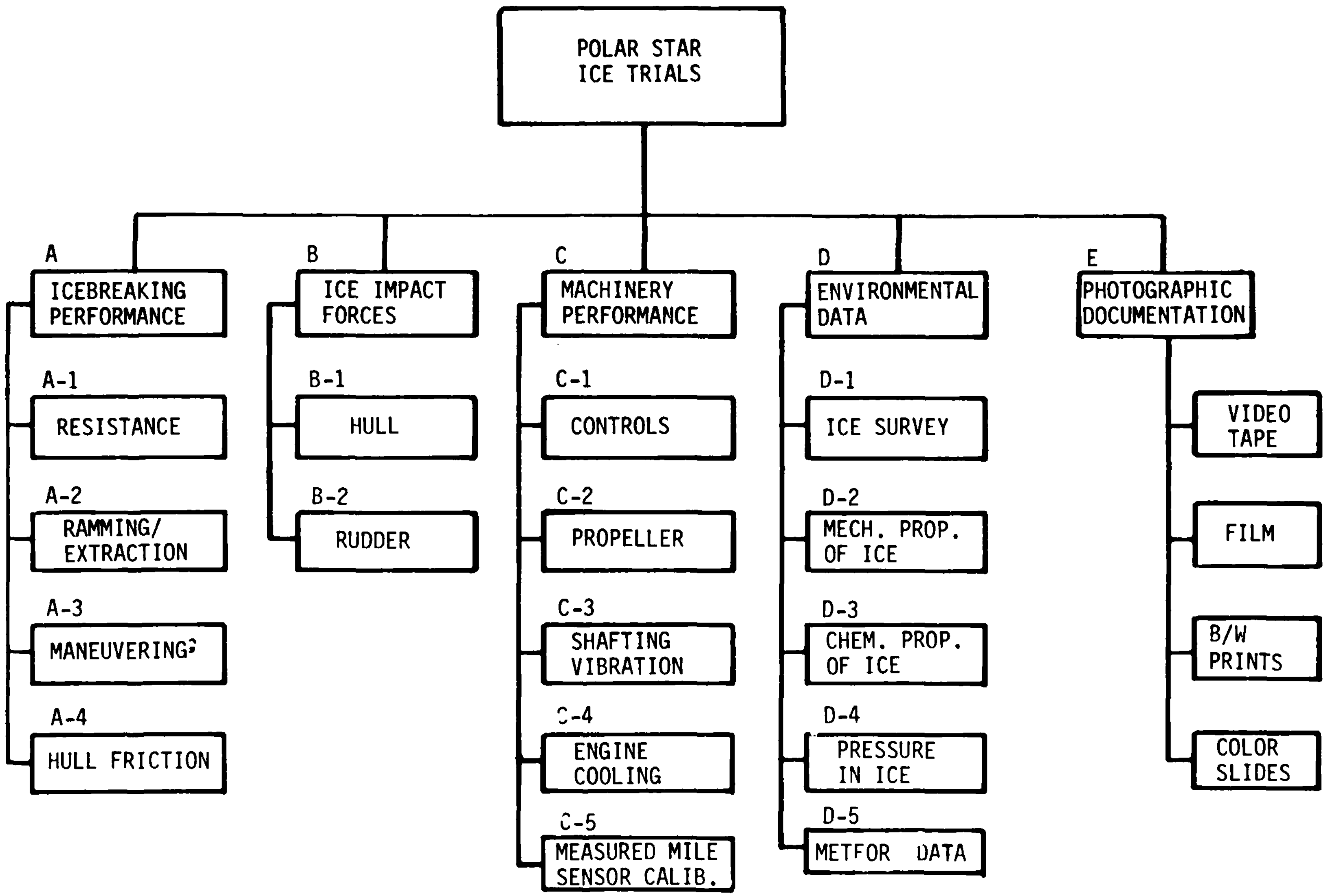


Figure 13. BREAKDOWN STRUCTURE OF THE TEST PLAN FOR THE USCGC POLAR STAR ICE TRIALS

SECTION A. ICEBREAKING PERFORMANCE

TEST PLAN A-1a
CONTINUOUS ICEBREAKING RESISTANCE

OBJECTIVE: To determine the continuous icebreaking capability of the POLAR STAR. This data will provide information on the speed-power relationships through various ice thicknesses and can be used in future operational planning.

DESCRIPTION OF TESTS: Figure 14 shows a test matrix as a functiontion of ice thickness and ship speed. Fifty data points are desired.

TEST OUTPUT: Ship's resistance vs. speed vs. ice thickness.

INSTRUMENTATION: The following parameters will be measured or calibrated from measured data:

- ship speed (radio position fixing system, doppler radar, and visual sightings)
- propeller shaft thrust (3 shafts)
- propeller shaft torque (3 shafts)
- propeller rpm (3 shafts)
- propeller pitch (3 propellers)
- roll and pitch angles
- pitch and surge accelerations
- draft of ship (forward and aft)
- ice thickness along ship's track
- depth of snow along ship's track
- flexural ice strength (from ice core - brine volume)
- wind speed and direction
- air temperature (dry bulb)
- estimated ice pressure

TEST PROCEDURE:

1. The POLAR STAR maneuvers into position and on a heading which will provide the longest possible test run commensurate with the floe size and shape. The ship must be positioned firmly in the floe to permit debarkation of personnel and equipment onto the test floe.

2. The Ice Teams debark with their equipment, including two all-terrain vehicles. The teams will survey and mark the ice ahead of the ship along the intended

Figure 14.

CONTINUOUS ICEBREAKING RESISTANCE

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED)

OBJECTIVE: 50 DATA POINTS AT DIFFERENT ICE THICKNESS AND VELOCITIES (147 BLANK SQUARES)

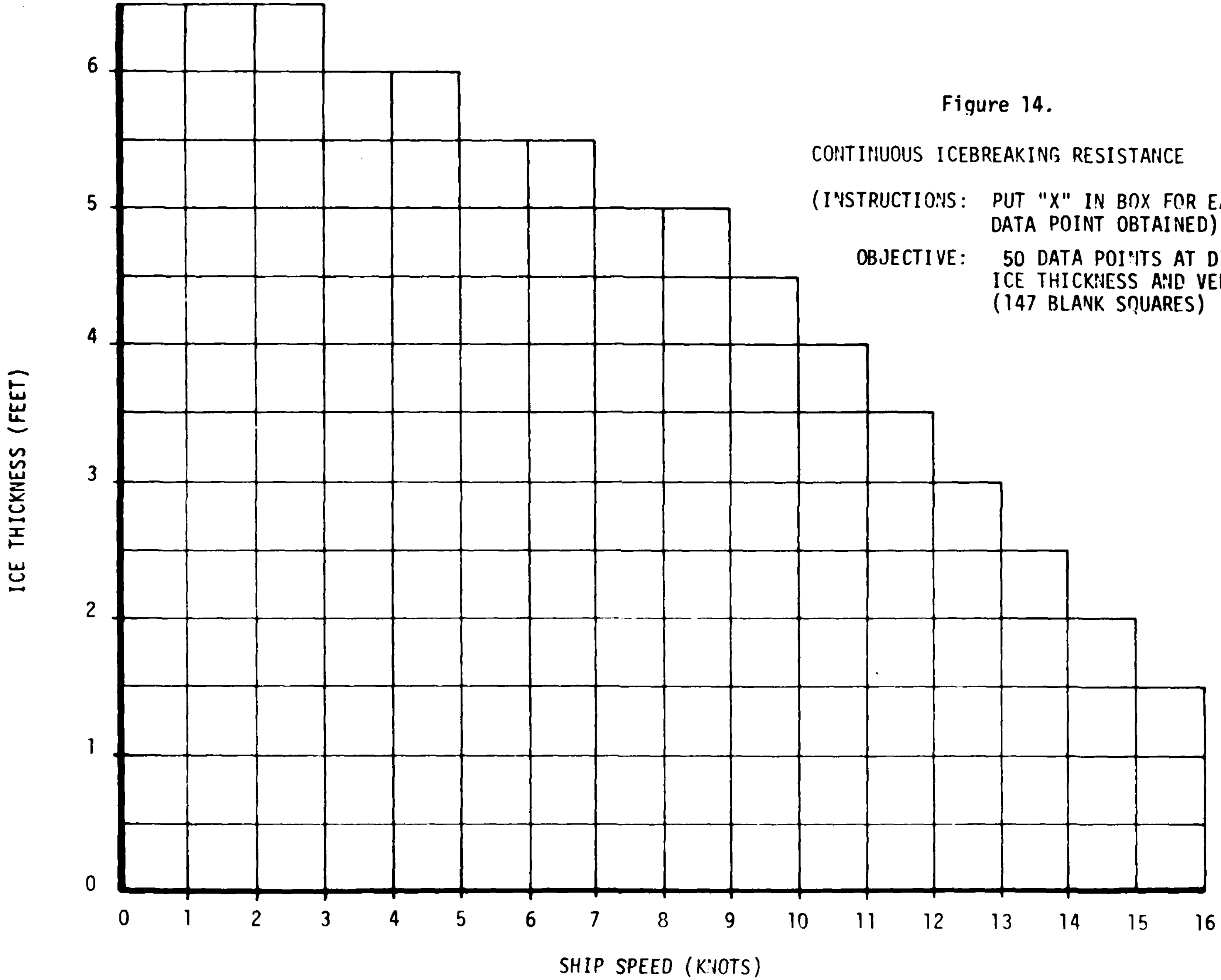
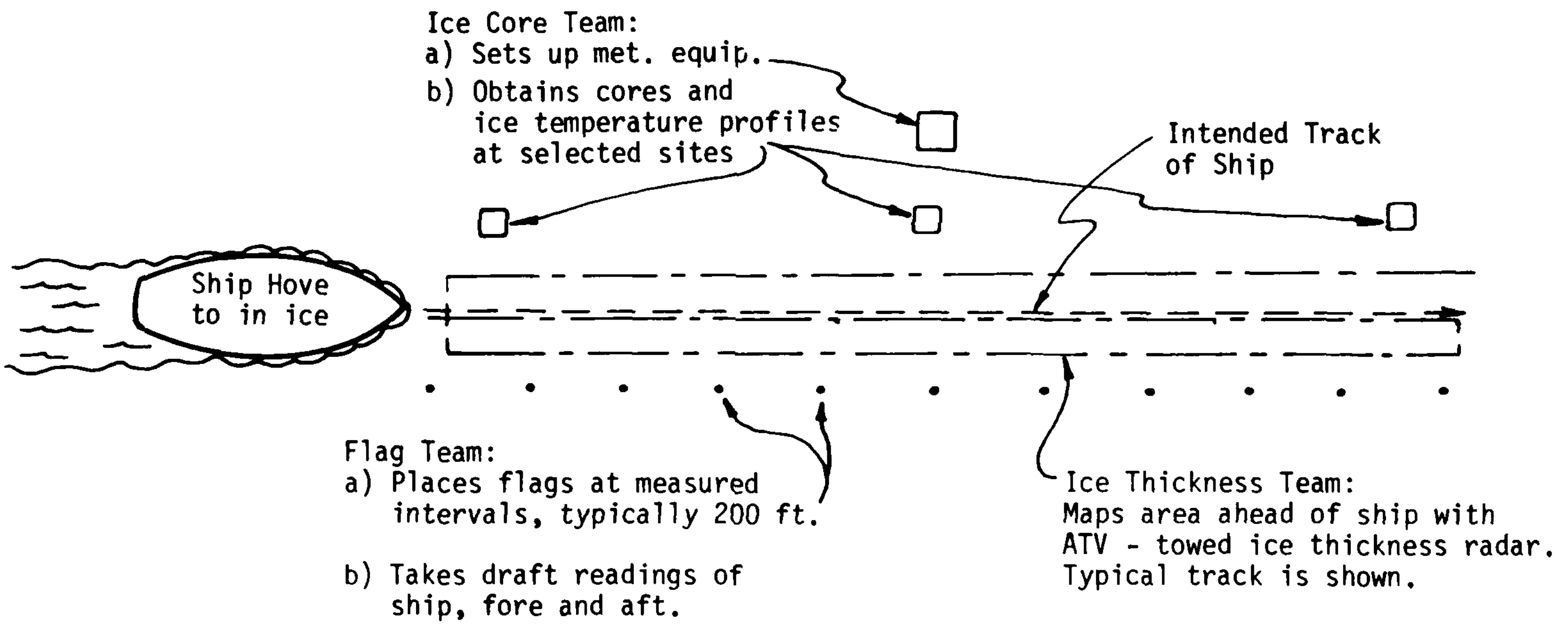


FIGURE 15

SHIP AND TEST TEAM DISPOSITION PRIOR TO CONTINUOUS ICEBREAKING TEST

All teams will work on same side of proposed ship track.
Teams shown on both sides only for graphic convenience.



track in accordance with pre-established plans. VHF-FM transceivers will be carried by on-ice personnel to permit ready communication with the ship. This activity is sketched in Figure 15.

3. During these two evolutions the shipboard personnel will check out the instruments and communication systems assigned to them.

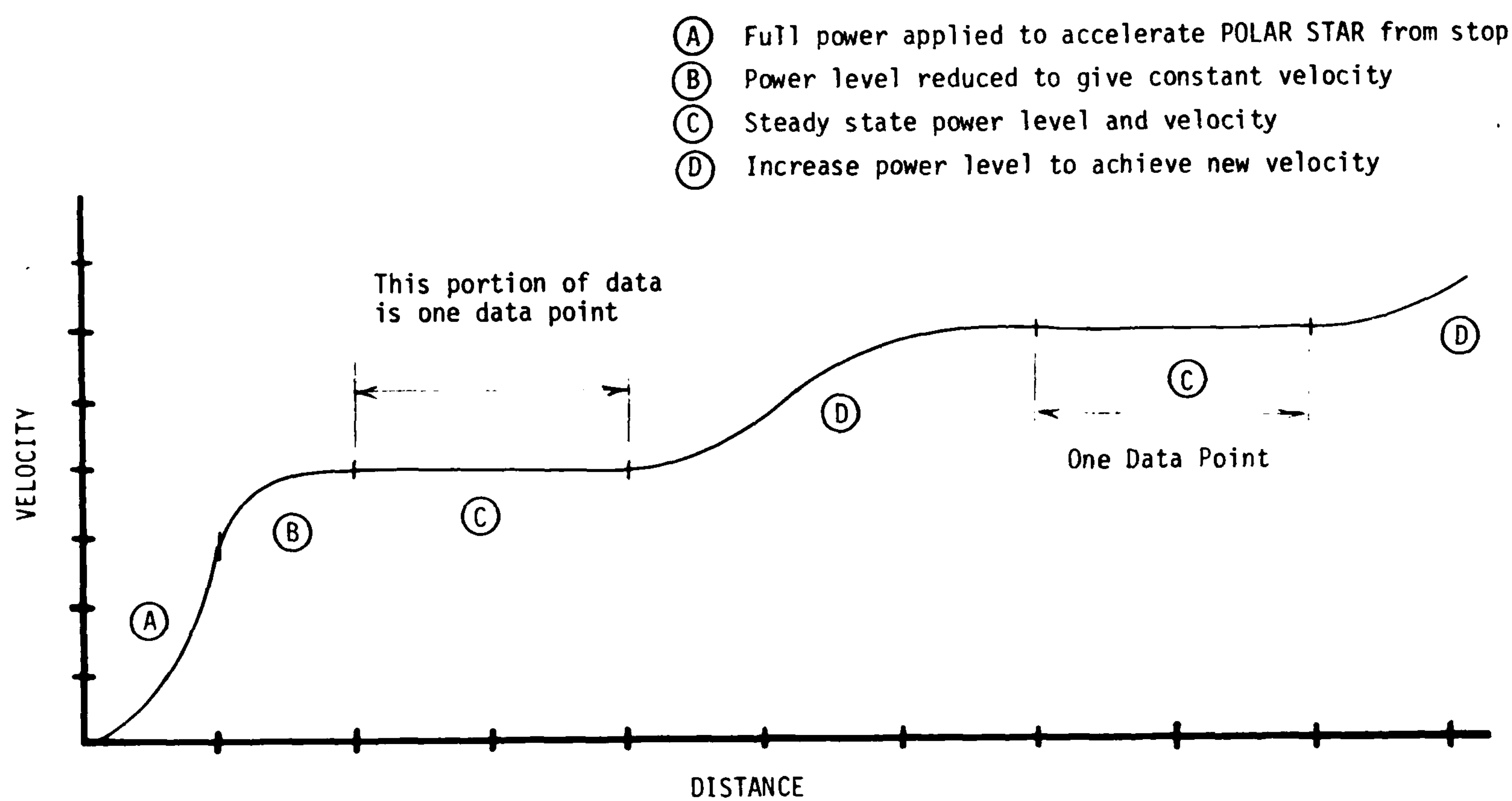
4. The test director will use the values of ice thickness obtained in the pre-test survey and his analysis of data taken prior to that test to determine the required amounts of power to be applied. The schedule will be developed with the Operations Officer and provided to the Commanding Officer and upon his approval, given to the Conning Officer, the Engineering Officer and the instrumentation team.

5. Motion pictures of the test will be taken in accordance with the requirements of Section E. The photographer will be stationed either on the ship or in a helicopter, depending on where the best view can be obtained.

6. The power on the propellers will be based on a pre-arranged schedule. Full power will be applied to start the ship moving through the ice field. As the ship continues to accelerate, the Test Director will select a time at which the power level is reduced and is held constant. The ship accelerations decrease, and a constant speed is obtained at that power level. The application of full power when starting is to get the ship up to speed as fast as possible. If the reduced power level was initially used, much of the ice field would be consumed during the acceleration period. Operation at a constant speed and constant power level is required for two ship lengths at which time the power level is increased to a new setting. The acceleration of the ship to a new constant speed should take just about three ship lengths. At this time, the ship will operate for two ship lengths at constant speed prior to increasing the power level. Figure 16 depicts the sequence of events. The sequence will be

Figure 16.

TYPICAL OPERATION DURING
CONTINUOUS ICEBREAKING TESTS



continued as long as suitable ice is available. Visibility between the ice team and the POLAR STAR must never be lost.

7. Wind speed and direction and air temperature will be recorded automatically throughout the test by on-ice equipment tended to by the Ice Core Team.

8. Draft readings (fore and aft) will be obtained by the Flag Team just prior to the test.

9. If the ice teams are to remain on the ice during the test, they will be ordered clear 15 minutes prior to applying power to the propellers.

10. After each run the Flag Team will recover as many of the speed/position marker flags as they can reach without jeopardy.

11. When all of the ice floe measurements have been completed, the ship will maneuver to pick up all ice parties and their equipment. Careful checks will be made to insure all personnel and equipment are back aboard ship. All team leaders will report to the Test Director upon completion of their tests and the recovery of their men and equipment. The Test Director will report to the OOD.

12. The ship will then get underway for the next suitable test location, having been selected preivously from helicopter reconnaissance.

TEST PLAN A-1b

STATIC (STARTING) ICEBREAKING RESISTANCE

OBJECTIVE: To determine the static or starting icebreaking resistance of the POLAR STAR as a function of ice thickness.

DESCRIPTION OF TESTS: Figure 17 shows a matrix of the types of tests planned. A minimum of 12 data points (3 in each of four thicknesses) are desired in level ice.

TEST OUTPUT: Resistance vs. ice thickness at 0 speed.

INSTRUMENTATION: Employ the same instrumentation used in continuous icebreaking tests.

TEST PROCEDURE:

Note: This test may be performed prior to or just after a continuous icebreaking test.

1. The POLAR STAR will coast to a natural stop when power is removed after continuous icebreaking as shown in Figure 17 and become wedged in the ice field.

2. The shipboard test teams take their positions and start their recording equipment upon signal from the Test Director.

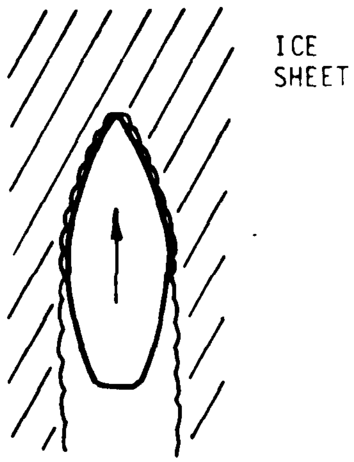
3. The Test Director initially specifies a power level to the Conning Officer. This power level is held for 30 seconds. If there is no ship movement, a new power level is specified and held for 30 seconds. The procedure is repeated until a power level is reached where the ship just begins to move. The test is then complete. The ship can then be stopped or power can be maintained and continuous data (Test A-1a) obtained.

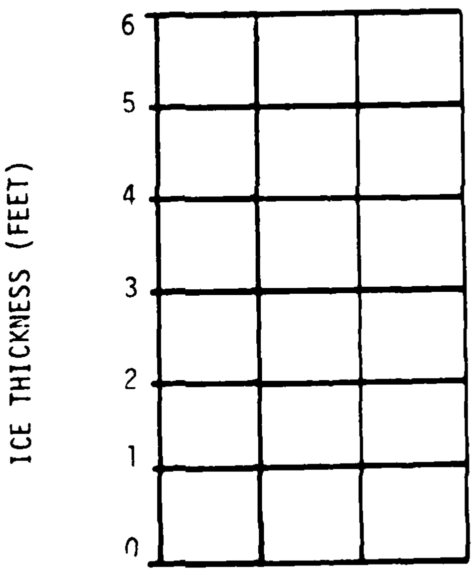
4. Meteorological and ice data and draft readings will be obtained as for Test A-1a.

Figure 17.

STARTING RESISTANCE

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED)





TEST PLAN A-1c

HEELING SYSTEM DURING CONTINUOUS ICEBREAKING

OBJECTIVE: To determine the effectiveness of the heeling system in reducing icebreaking resistance during continuous mode icebreaking. This will provide information on the value of employing the heeling system during slow but steady continuous icebreaking operations in heavy ice.

DESCRIPTION OF TESTS: Figure 18 shows a matrix of tests as a function of sheet ice thickness and ship speed. At least five data points are desired. The tests with the heeling system should be performed immediately following a continuous icebreaking test in the <u>same ice thickness</u> and <u>shaft horsepower</u>.

TEST OUTPUT: Resistance vs. heeling system operations.

INSTRUMENTATION: Employ the same instrumentation used in continuous icebreaking tests with the addition of recording heeling pump cycle time and ship heel.

TEST PROCEDURE:

Note: This test immediately follows a continuous icebreaking test in the sense that the ship continues at the previous steady state speed when the heeling system is activated. Tests should be conducted at ship speeds under 5 knots.

1. After traveling the desired 800 feet at a steady state speed in continuous icebreaking mode, the Test Director will say "mark" to all data recording stations. At this time a note will be made on the data paper that the heeling system was activated. Concurrently, the heeling pump is started and set for maximum roll at minimum cycle time.

2. The ship should travel a distance at least equal to one full roll cycle or 1,000 feet.

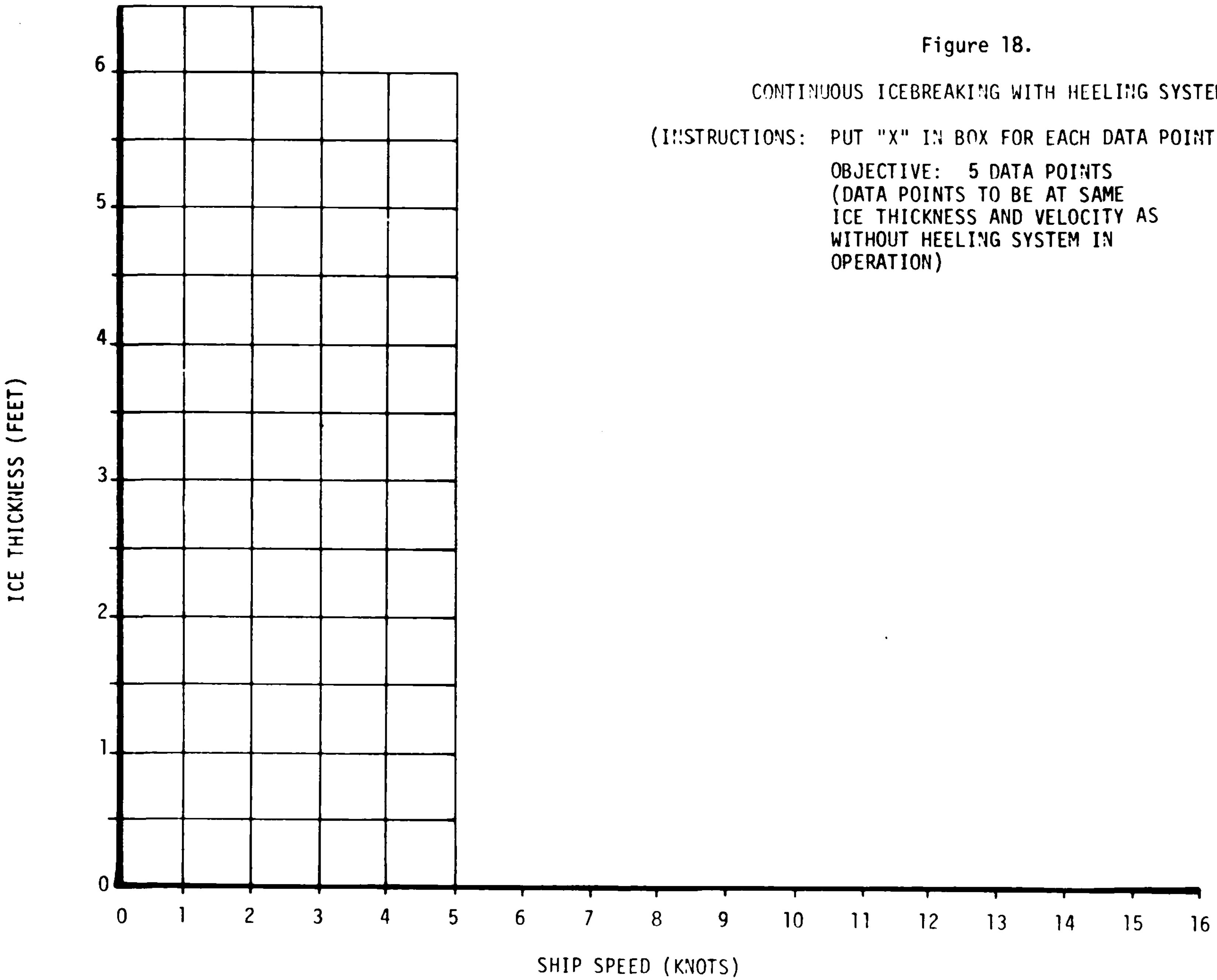
3. Ice and meteorological data will be obtained in the same manner as in Test A-1a.

Figure 18.

CONTINUOUS ICEBREAKING WITH HEELING SYSTEM

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED)

OBJECTIVE: 5 DATA POINTS
(DATA POINTS TO BE AT SAME ICE THICKNESS AND VELOCITY AS WITHOUT HEELING SYSTEM IN OPERATION)



TEST PLAN A-1d

CLOGGED CHANNEL RESISTANCE

OBJECTIVE: To determine the resistance of the POLAR STAR in ice clogged channels.

DESCRIPTION OF TESTS: Figure 19 shows a matrix of tests as a function of sheet ice thickness and ship speed. Five data points are desired. In general, the tests will be performed after a continuous icebreaking resistance test.

INSTRUMENTATION: Employ the same instrumentation used in continuous icebreaking tests.

TEST PROCEDURES:

1. The POLAR STAR maneuvers into the broken channel.

2. The ice teams may remain on the ice performing experiments but at a safe distance from the broken channel. The speed flags will be set up.

3. Detail test plan reviewed with Commanding Officer. Upon C.O.'s approval, Conning Officer, Engineering Officer and Instrumentation Team are notified.

4. Meteorological data is recorded. Still photos of the channel are taken from a high point on the ship or from a helicopter to record percent ice coverage in the channel.

5. All recording equipment is started and zero levels recorded for the same instrumentation used in continuous icebreaking. Additionally, channel width, average piece size and the percent of the channel surface area covered with ice will be recorded.

6. When all stations report ready, power is applied to the propellers in accordance with the test plan. When constant power and constant speed are obtained for 800 feet, a steady state resistance value is obtained.

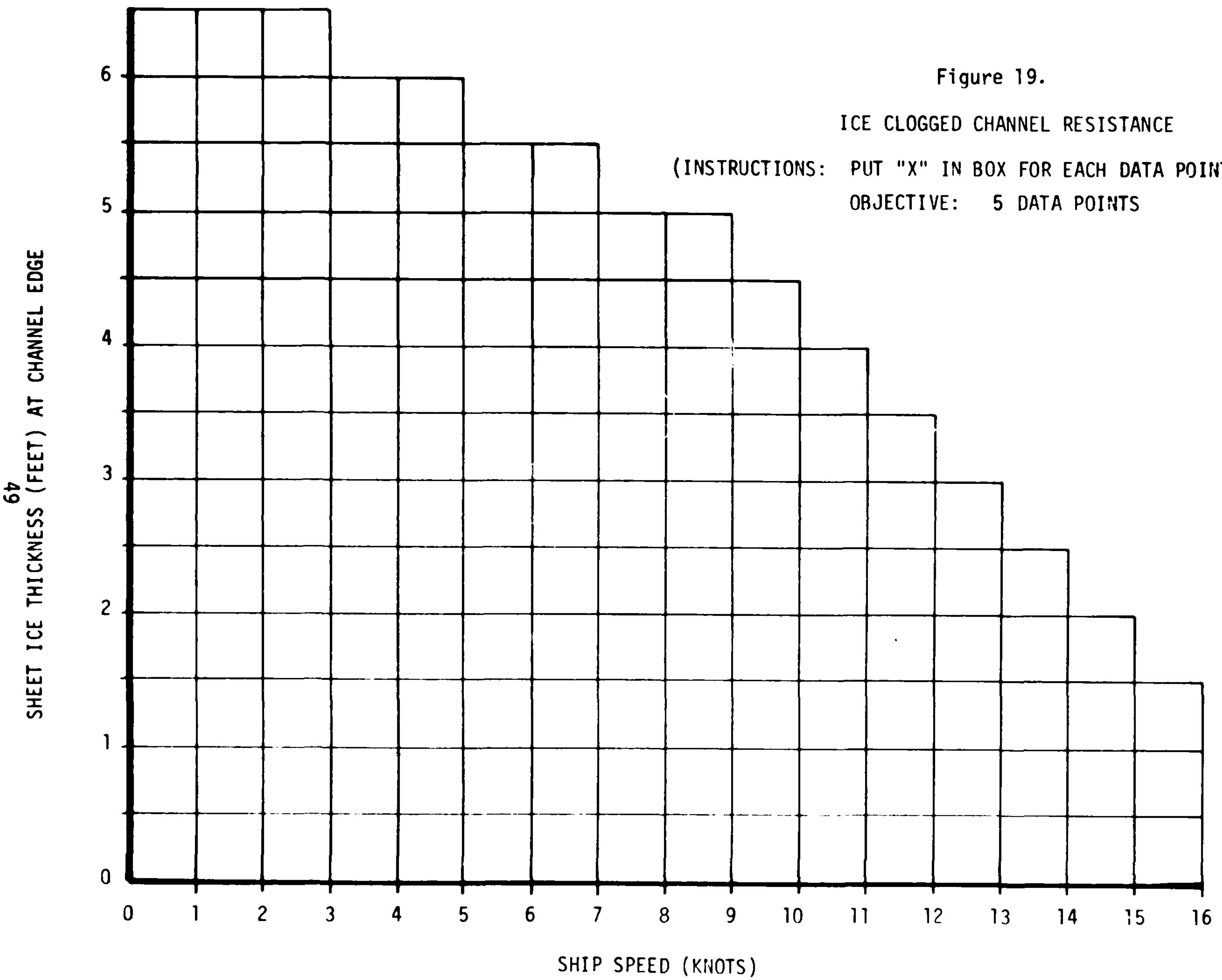
7. Power level and speed are increased to a new level in accordance with the test plan.

Figure 19.

ICE CLOGGED CHANNEL RESISTANCE

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED)

OBJECTIVE: 5 DATA POINTS



TEST PLAN A-2a

RAMMING AND EXTRACTION RESISTANCE IN LEVEL ICE

OBJECTIVE: To determine the ramming capability of the POLAR STAR in uniform ice in terms of penetration distance as a function of impact speed, ice thickness, and propeller thrust.

DESCRIPTION OF TESTS: Figure 20 shows a matrix of tests for power levels of 18,000 and 60,000 SHP. Ten data points (5 in each of two different thicknesses) are desired in uniform thickness ice.

TEST OUTPUT: (a) ram penetration vs. ice thickness vs. impact speed.

(b) extraction resistance vs. ice thickness (Fig. 21).

(c) Resistance vs. velocity.

INSTRUMENTATION: Employ the same instrumentation used in continuous icebreaking tests.

TEST PROCEDURE (Fig. 22):

1. The POLAR STAR enters the ice field for a distance of about 1,200 feet and comes to a stop.

2. The Ice Thickness and Ice Core Teams obtain ice data as done in the continuous icebreaking tests (A-1a).

3. The shipboard test teams checkout all instruments and communication systems.

4. The Test Director will prepare a schedule which will include the number of penetration runs to be attempted, the stand-off distances used to ram for each run and the power level to be used just prior to impact for each run. The schedule will be provided to the Commanding Officer. Upon his approval it will be given to the Conning Officer, the Engineering Officer and the instrumentation center.

5. The Flag Team will mark a point abeam of the point of contact between the bow and the ice with a flag. A second flag will be located aft of the first at a distance to be specified by the Test Director. Both flags will be located outside the path to be broken by the ship.

6. The POLAR STAR is backed out of its present position to a new position abeam of the second flag and all propellers will be stopped. The distance between the two flags is the acceleration distance. When the ship's hull is clear of the ice in the area of the instrumented bow section, the shafts will be stopped, the recording equipment will be started and "zero levels" recorded and noted. When the instrumentation team leader is satisfied that the equipment is zeroed and ready, he will notify the Test Director in the pilot house.

7. Meteorological data is recorded by equipment set up on the ice and the helicopter is launched to carry a photographer aloft.

8. When all stations report ready, the Test Director will request the Conning Officer to apply power as scheduled.

9. The Flag Team will notify the Test Director when the ship is stopped. All recording equipment will be marked at the time when the ship stops.

10. After the ship comes to a stop, full ahead power will be removed from the propellers and an astern power level will be applied as specified by the Test Director. The astern power level will be specified in increments to determine the minimum power level to extract the ship. The Test Director will also specify whether or not the heeling system is to be employed during the extraction test. During some of the extraction tests, attempts will be made to "twist" the ship from the stuck position by swinging the rudder back and forth and by changing power levels on the outboard propellers.

11. Precise measurement of the penetration distance during the ram will be made by the Flag Team; they will also record the ship's draft fore and aft.

12. Friction tests should be conducted in conjunction with this test as outlined in Test Plan A-4.

13. When the ice teams have completed their measurements, the ship will maneuver to a safe and accessible location to receive the Ice Team personnel and equipment remaining on the ice. Careful checks of all personnel and equipment will be made to insure that no

people or instruments are still left on the ice. The team leaders will report to the Test Director and the Test Director will report to the OOD when this has been accomplished.

Figure 20.

RAMMING ICEBREAKING RESISTANCE - UNIFORM ICE

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED
PUT "O" IN BOX WHEN HEELING SYSTEM IN OPERATION)

OBJECTIVE: 10 DATA POINTS
(56 BLANK SQUARES)

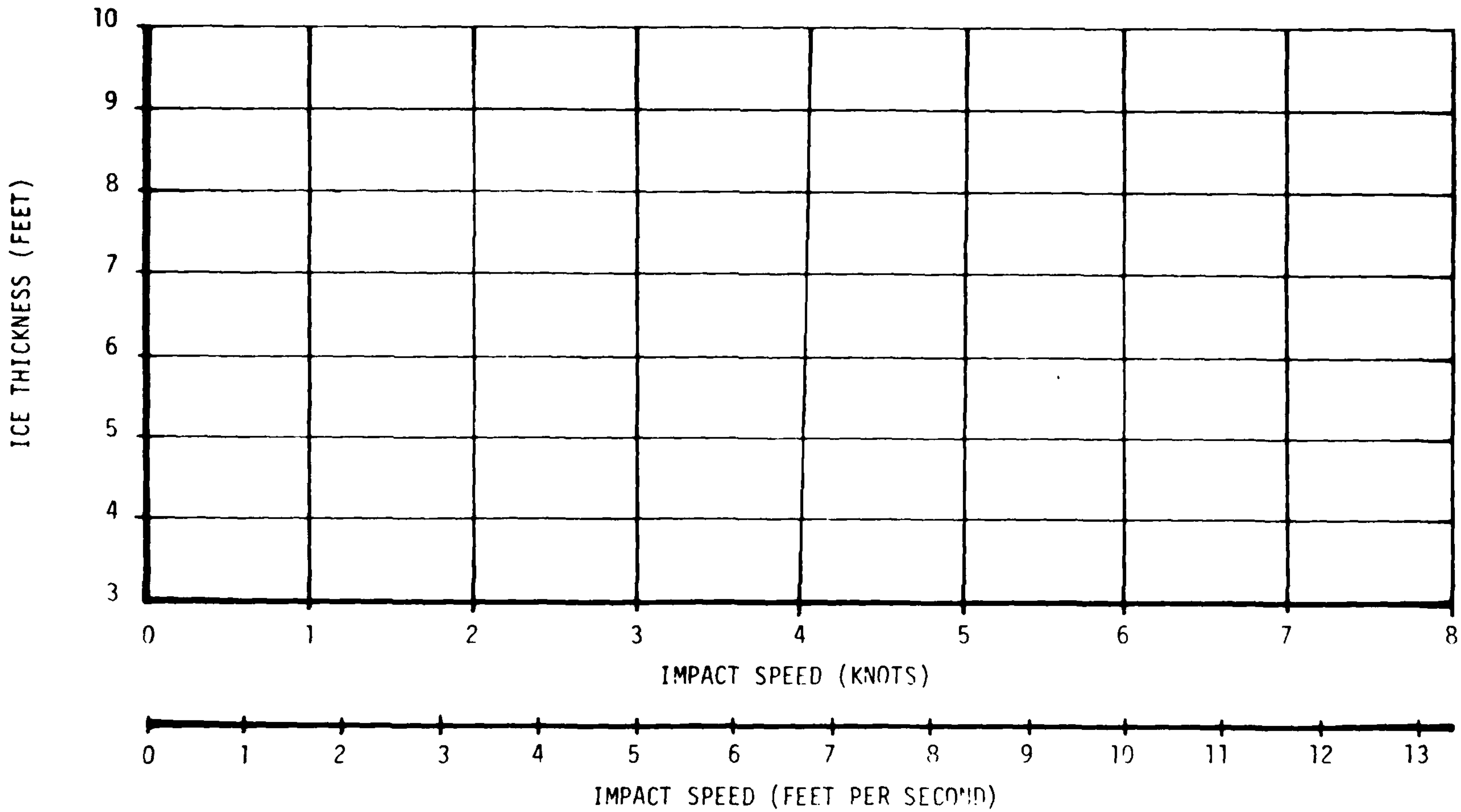


Figure 21

EXTRACTION RESISTANCE AFTER RAM

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED
PUT "O" IN BOX WHEN HEELING SYSTEM IN OPERATION
PUT "Δ" IN BOX WHEN TWISTING)

OBJECTIVE: 10 DATA POINTS
(84 BLANK SQUARES)

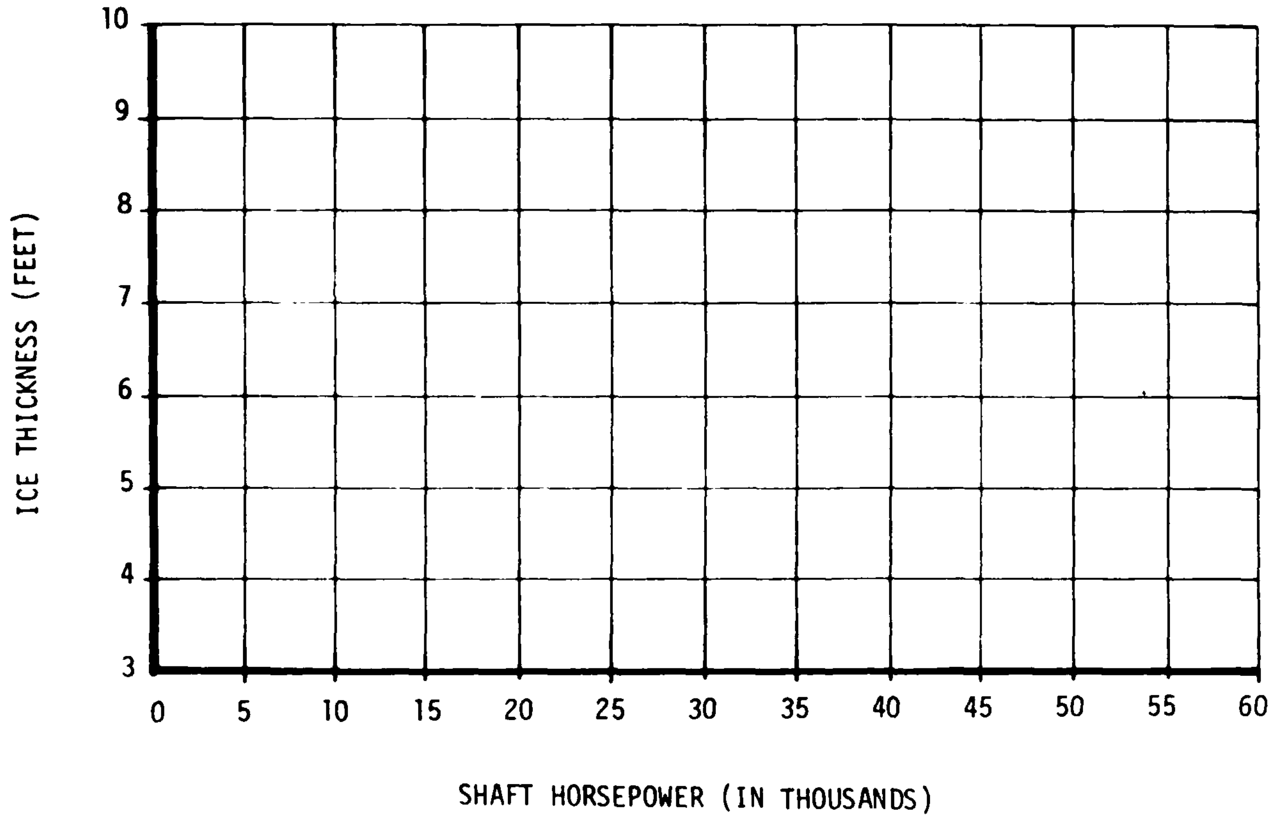
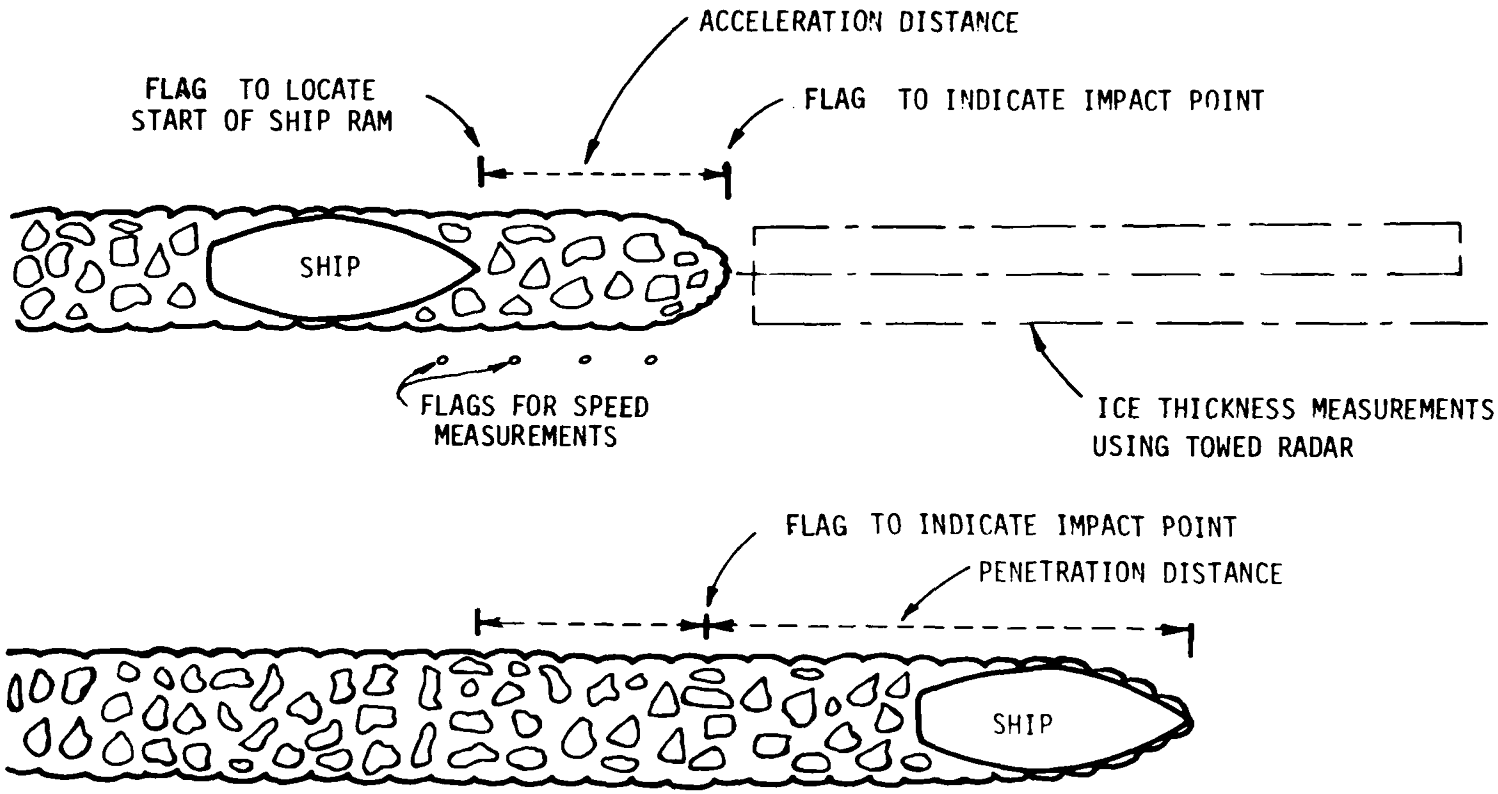


Figure 22

RAMMING SEQUENCE IN UNIFORMLY THICK ICE



TEST PLAN A-2b

RAMMING AND EXTRACTION RESISTANCE IN PRESSURE RIDGES

OBJECTIVE: To determine the ramming capability of the POLAR STAR in pressure ridges in terms of penetration distance as a function of impact speed, pressure ridge characteristics, and propeller thrust. This information will provide data for future operational planning on the speed of advance of the ship through pressure ridged ice fields.

DESCRIPTION OF TESTS: Figure 23 shows a matrix of tests for five different classes of pressure ridges. Fifteen data points are desired as many pressure ridges are expected in the test area.

TEST OUTPUT: (a) penetration vs. impact speed vs. ridge size

(b) extraction resistance vs. ridge size (Fig. 25).

INSTRUMENTATION: Employ the same instrumentation used in continuous icebreaking tests.

TEST PROCEDURE (Fig. 24):

Note: It is highly desirable to have motion pictures of these tests taken from either the ice or from the helicopter.

1. The ice team will map the pressure ridge area using plane table and alidade methods. The alidade will be used to determine the time of ridge impact. The instrument will be set up at a distance of about 600 feet from the expected point of impact and at an angle to the impact face of the ridge. Height and width will be indicated on the map. Subsurface dimensions will be obtained using sonar. The ice team may drill one hole on each side of the ridge and using a "candlestick" sonar profile the pressure ridge keel.

2. The POLAR STAR proceeds through uniform sheet ice with the instrumentation system in operation and impacts a pressure ridge. At the time of impact, an observer on the ice will advise the Test Director in the pilot house, by radio, who will give a "mark" to the instrumentation room. The ship will

either go through the pressure ridge or will come to a stop after a partial penetration.

3. For the case of total penetration through the pressure ridge, the ship will maintain full power for about 800 feet at which time the ship will stop. The ice teams then measure the height, width and angle at or near the point where the ship impacted the pressure ridge. Meteorological data is recorded and pictures taken from an aloft position on the ship.

4. For the case of partial penetration through the pressure ridge, the ship is backed out of the pressure ridge to a distance of 80Q feet at which time the ice teams record the depth of initial ship penetration. A flag will be placed abeam of the initial penetration point and the distance to the bow of the ship recorded.

5. When the ice team is clear of the pressure ridge, the Conning Officer will apply power to a level approved by the Commanding Officer. If the ship successfully penetrates through the pressure ridge, power will be maintained for 800 feet at which time the ship is stopped. If the ship was unable to penetrate the pressure ridge, a second flag will be placed abeam of the ship to show the extent of penetration. After the ship comes to a stop, ahead power will be removed from the propellers and the ice team will measure the distance of penetration. Astern power will be applied as specified by the Test Director. The astern power level will be specified in increments to determine the minimum power level to extract the ship. The Test Director will also specify whether or not the heeling system is to be employed during the extraction test. During some of the extraction tests, attempts will be made to "twist" the ship from the stuck position by swinging the rudder back and forth and by changing power levels on the outboard propellers.

6. When the ice teams have completed their measurements, the ship will maneuver to pick up all test party personnel and equipment remaining on the ice. The Test Director will report to the OOD when all are aboard.

Figure 23

RAMMING ICEBREAKING RESISTANCE - PRESSURE RIDGES

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED
PUT "O" IN BOX WHEN HEELING SYSTEM IN OPERATION)

OBJECTIVE: 15 DATA POINTS
(40 BLANK SQUARES)

PRESS. RIDGE CLASS	HEIGHT (FT)	WIDTH (FT)	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8
5	8-	16-								
4	6-8	12-16								
3	4-6	8-12								
2	2-4	4-8								
1	0-2	0-4								

0 1 2 3 4 5 6 7 8

IMPACT SPEED (KNOTS)

0 1 2 3 4 5 6 7 8 9 10 11 12 13

IMPACT SPEED (FEET PER SECOND)

Figure 24

RAMMING A PRESSURE RIDGE

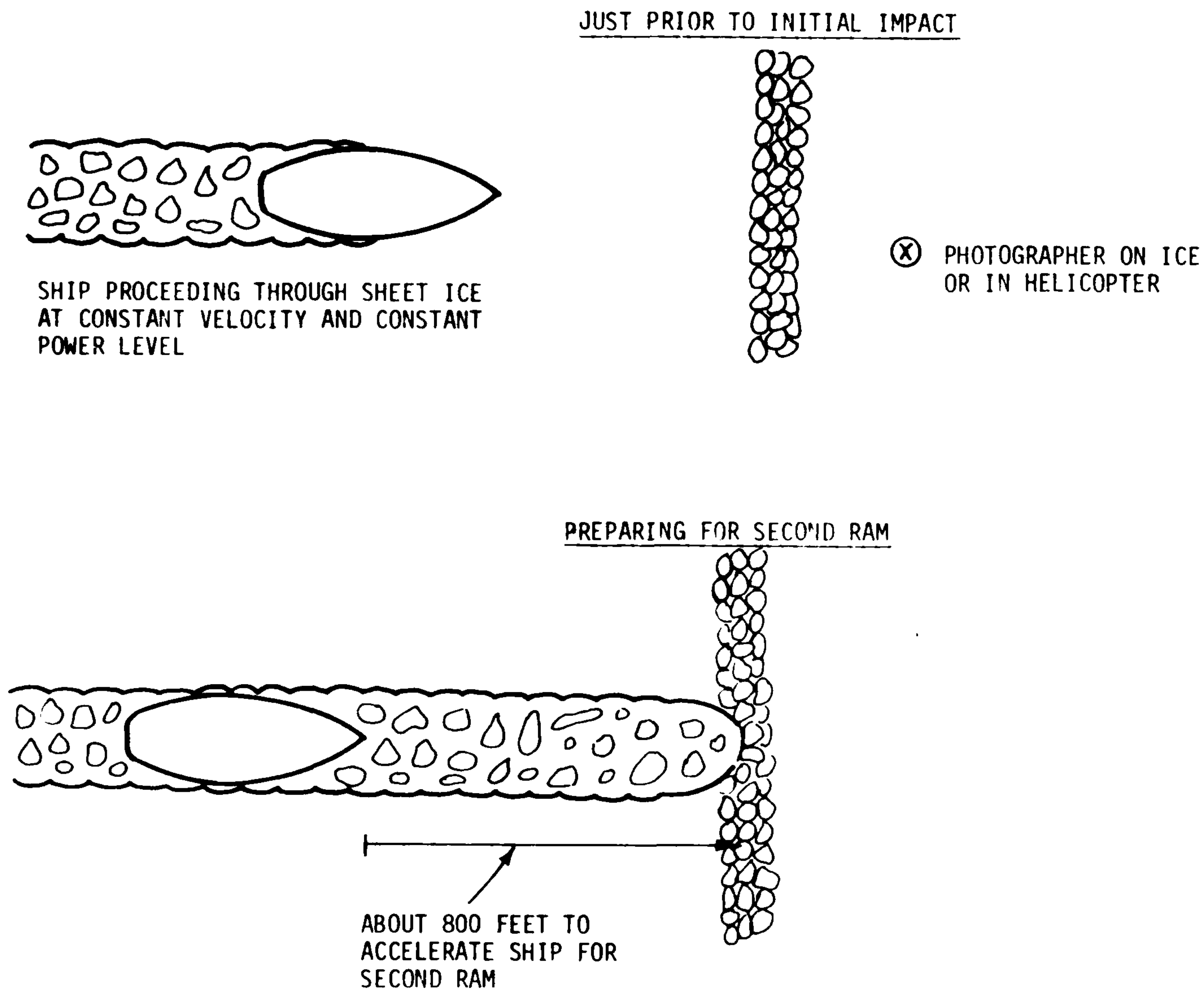


Figure 25

EXTRACTION RESISTANCE AFTER RAM - PRESSURE RIDGES

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED
PUT "O" IN BOX WHEN HEELING SYSTEM IN OPERATION
PUT "Δ" IN BOX WHEN TWISTING)

OBJECTIVE: 15 DATA POINTS
(60 BLANK SPACES)

PRESS. RIDGE CLASS	HEIGHT (FT)	WIDTH (FT)												
5	8-	16-												
4	6-8	12-16												
3	4-6	8-12												
2	2-4	4-8												
1	0-2	0-4												

0 5 10 15 20 25 30 35 40 45 50 55 60

PENETRATION (FEET)

TEST PLAN A-3

MANEUVERING - TURNING CIRCLE

OBJECTIVE: To determine the turning circle radius in different thicknesses of ice at full power ahead on diesels and gas turbines with full rudder. This will provide useful data for ship operation as well as provide design data for the naval architect.

DESCRIPTION OF TESTS: Figure 26 shows a test matrix as a function of ice thickness, power, and rudder position.

TEST OUTPUT: Tactical diameter, etc., vs. ice thickness vs. shaft horsepower.

INSTRUMENTATION: The instrumentation and variables required to be measured are the same as for the continuous icebreaking resistance tests listed in TEST PLAN A-1a. In addition, it will be necessary to plot the position of the ship with time at least every one minute in order to determine the path of the ship as shown in Figure 27. This will be accomplished by the use of one of three methods; the choice will depend on equipment available and the prevailing conditions at the time of the test. The three methods are:

(a) The use of a electronic precision navigation system (i.e., "Mini-Ranger"),

(b) the erection of temporary masts on the ice, which would be used as conventional landmarks by the bridge personnel, or

(c) the use of a surveyor's alidade to measure the range and bearing of the ship from a point on the ice.

All of the above techniques require a certain amount of conventional surveying prior to and in preparation for the tests. This will be accomplished by a special team of R&DC personnel.

TEST PROCEDURE:

1. The positioning technique is selected and the required preparatory surveying completed.

2. An approach is made at the desired power level and the ship advancing on a straight path.

3. The rudder is put over right 30° or left 30° as required.

4. The rudder is kept over until the ship has turned through 360°, then the ship will be stopped.

5. During the turn, measurements will be made every minute from which the advance, transfer, tactical diameter and steady turning radius can be determined.

6. Measurements of ice and meteorological data will be made similarly to those for Test A-la.

Figure 26

MANEUVERING - TURNING CIRCLE

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED)

TEST	PORT	CENTER	STBD	RUDDER POSITION
1	6,000 (D)	6,000 (D)	6,000 (D)	30° Right
2	6,000 (D)	6,000 (D)	6,000 (D)	30° Left
3	20,000 (GT)	20,000 (GT)	20,000 (GT)	30° Right
4	20,000 (GT)	20,000 (GT)	20,000 (GT)	30° Left

ICE THICKNESS (FEET)

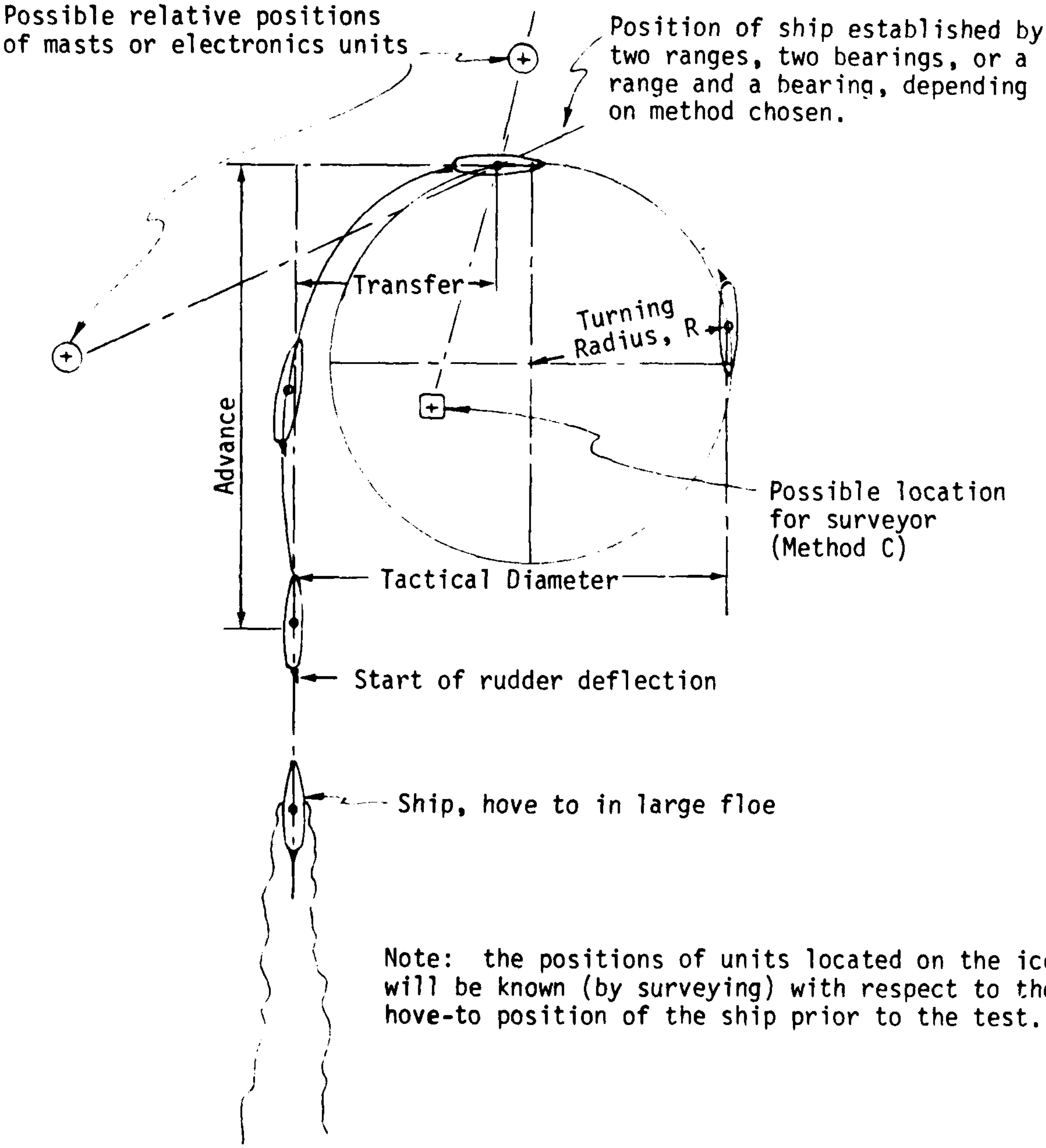
1 2 3 4 5 6

(D) - Diesel Electric

(GT) - Gas Turbine

FIGURE 27

TURNING PATH OF AN ICEBREAKER



Note: the positions of units located on the ice will be known (by surveying) with respect to the hove-to position of the ship prior to the test.

TEST PLAN A-4

HULL-ICE FRICTION TEST

OBJECTIVE: To determine the coefficient of friction between ice and the hull plating of the POLAR STAR.

DESCRIPTION OF TEST: The friction test apparatus is sketched in Figures 28 and 29. It consists of a carriage which rides on a rail along the side of the ship, the rail being held onto the hull by electromagnets. A block of ice is positioned in a holder on the carriage and is pressed against the hull of the ship. By towing the carriage along the rail and measuring the normal force and the friction force, the friction factor between the hull and the ice can be determined.

By supporting the rail with electromagnets, the rail can be positioned along the waterline. In addition, the carriage has been designed so that the test can be run with the block of ice submerged or above water. Due to the weights involved, the tests will most probably be run below one of the ship's cranes.

The normal force between the hull and ice can be increased by adding lead weights to the carriage. A normal force up to 500 lbs. can be achieved with lead weights of 300 lbs. This limit is determined by the holding power of the magnets.

TEST OUTPUT: Coefficients of kinetic and static friction.

INSTRUMENTATION: Instrumentation will be used to measure:

- towing or friction force at ice block
- normal force on ice block
- velocity of carriage

SPECIAL EQUIPMENT:

- Test apparatus shown in Figures 28 and 29
- Ice cutting equipment to cut ice blocks

TEST PROCEDURE:

1. The rail has to be put in place. This will require working from the ice or from a small boat. The rail assembly will be lowered over the side with the ship's crane or by handlines. When in position, the magnets will be energized to support the rail.

2. While the rail is being positioned, an ice party can cut a block of ice approximately one foot on a side. This can be brought aboard and installed in the carriage while the carriage is still on deck. The lead weights can then be added to the carriage. When all is ready, the carriage can be lifted by the ship's crane and lowered over the side on the rail. The desired tests can then be run.

3. If tests are run with the ice block submerged, the hydrodynamic drag must be determined. The ice block should be measured and weighed in order to determine buoyancy forces.

4. This test can be conducted at night with proper lighting from the ship. In this manner, maximum use of daylight hours can be made for icebreaking tests. However, if sufficient manpower is available, this test will be run during the day during periods when the ship is hove to awaiting the completion of other ice measurements.

5. After several blocks of ice have been tested, the equipment will be struck down and brought on board.

6. As a backup to the above equipment, a special sled will be available for use to obtain ice-steel friction measurements. After being lowered onto the ice by a crane, the (instrumented) sled is towed by hand or with an ATV. Other than crane service, the operation of the sled will not require assistance from the ship.

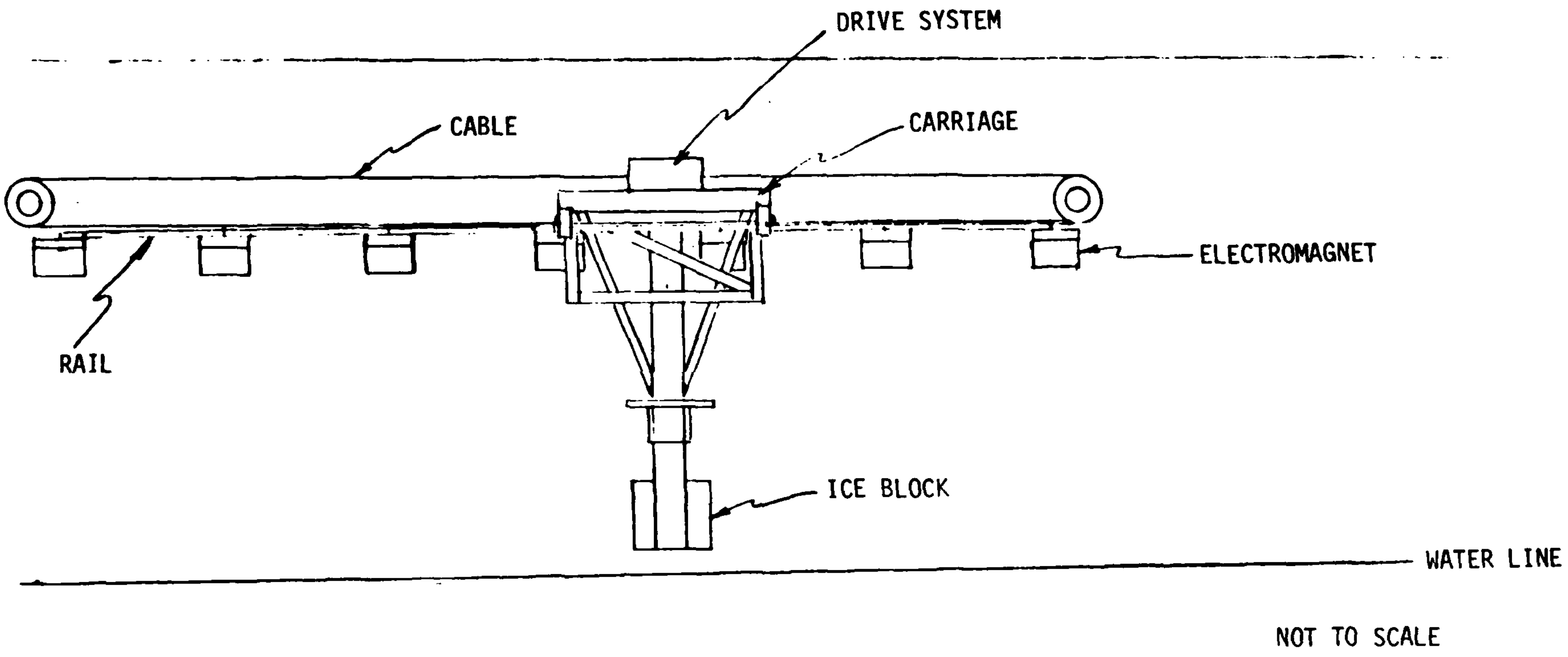


FIGURE 28

FRONT VIEW OF FRICTION APPARATUS

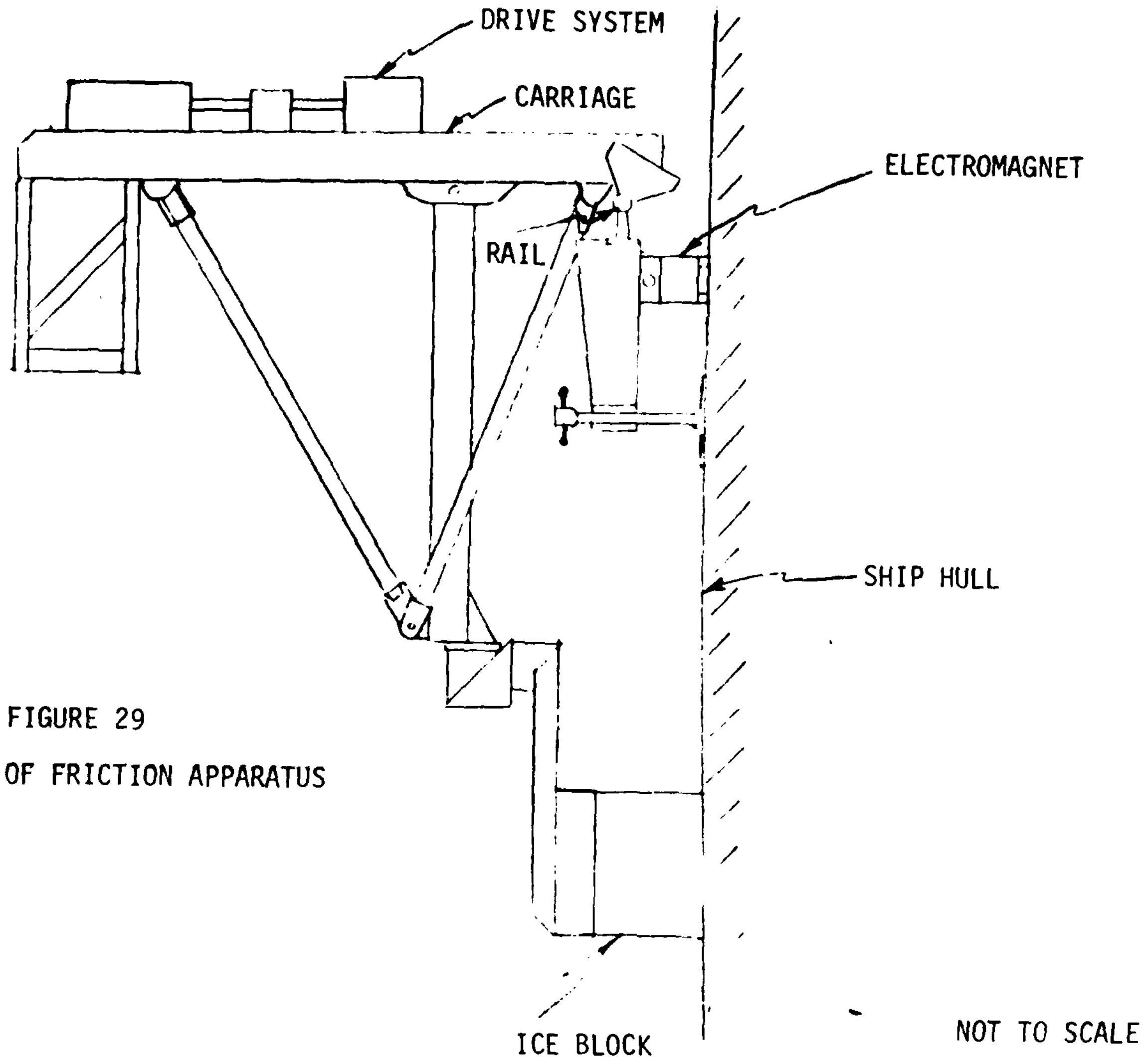


FIGURE 29

SIDE VIEW OF FRICTION APPARATUS

SECTION B. ICE IMPACT FORCES

TEST PLAN B-1

HULL IMPACT FORCES

OBJECTIVE: To determine the ice impact forces on the bow of the POLAR STAR for the locations shown in Figure 30.

DESCRIPTION OF TESTS: Figures 31 through 35 show the matrix of tests. In general, the measurement of ice impact forces will be concurrent with all other tests designed to determine ship performance in ice.

TEST OUTPUT: Peak load vs. speed.

INSTRUMENTATION: The following parameters will be measured or calculated from other measurements:

- strain levels from strain gages
- ship speed
- ice thickness along ship's track
- depth of snow along ship's track
- flexural ice strength (from brine volume)
- draft of ship (forward and aft)
- wind speed and direction
- air temperature (wet and dry)

TEST PROCEDURE:

1. Recording instrumentation is warmed up and communications established with the Test Director.

2. Upon instruction from the Test Director, the recording equipment is operated and strain gage readings recorded.

3. For ice floe collision data (Fig. 35), sufficient acceleration distance will be utilized so that the floe impact speed can be assumed to be the same as the open water steady state speed for the selected power level.

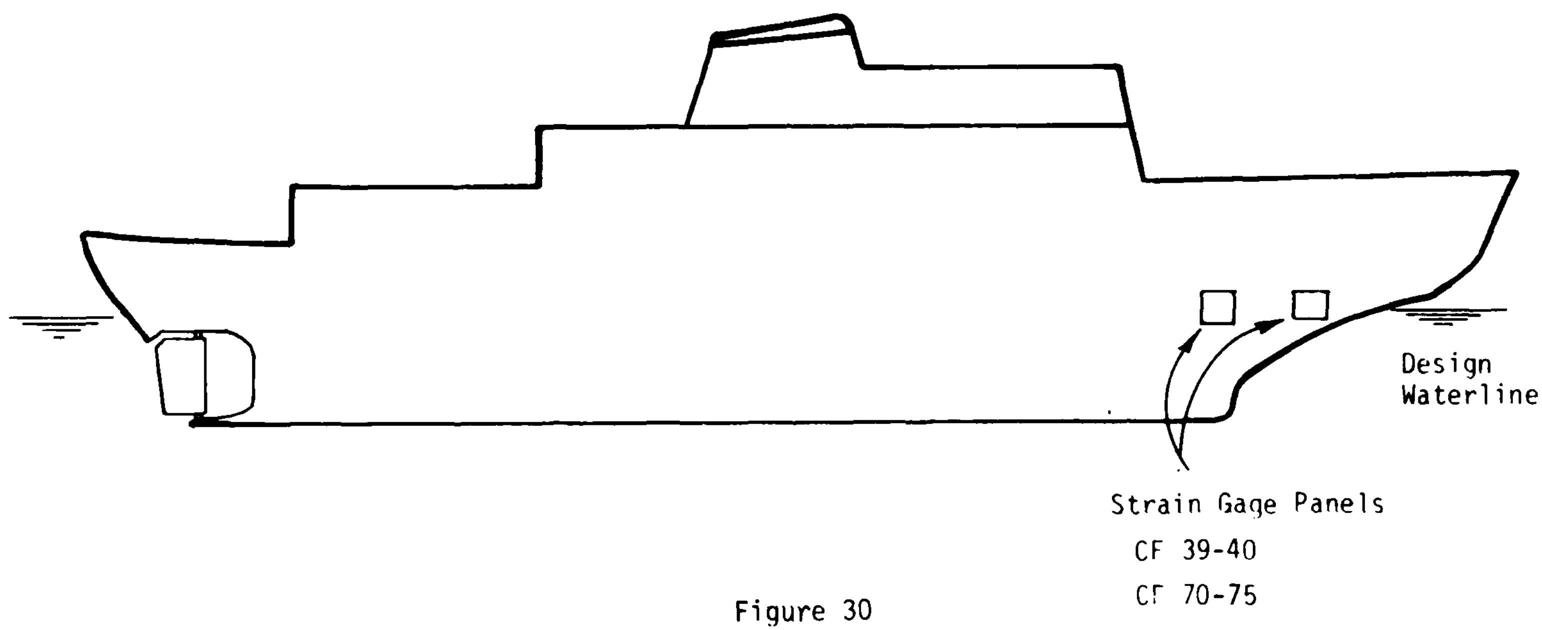


Figure 30

STRAIN GAGE PANELS

Figure 31

HULL IMPACT FORCES DURING CONTINUOUS ICEBREAKING

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED)

OBJECTIVE: 50 DATA POINTS AT DIFFERENT ICE THICKNESS AND VELOCITIES (147 BLANK SQUARES)

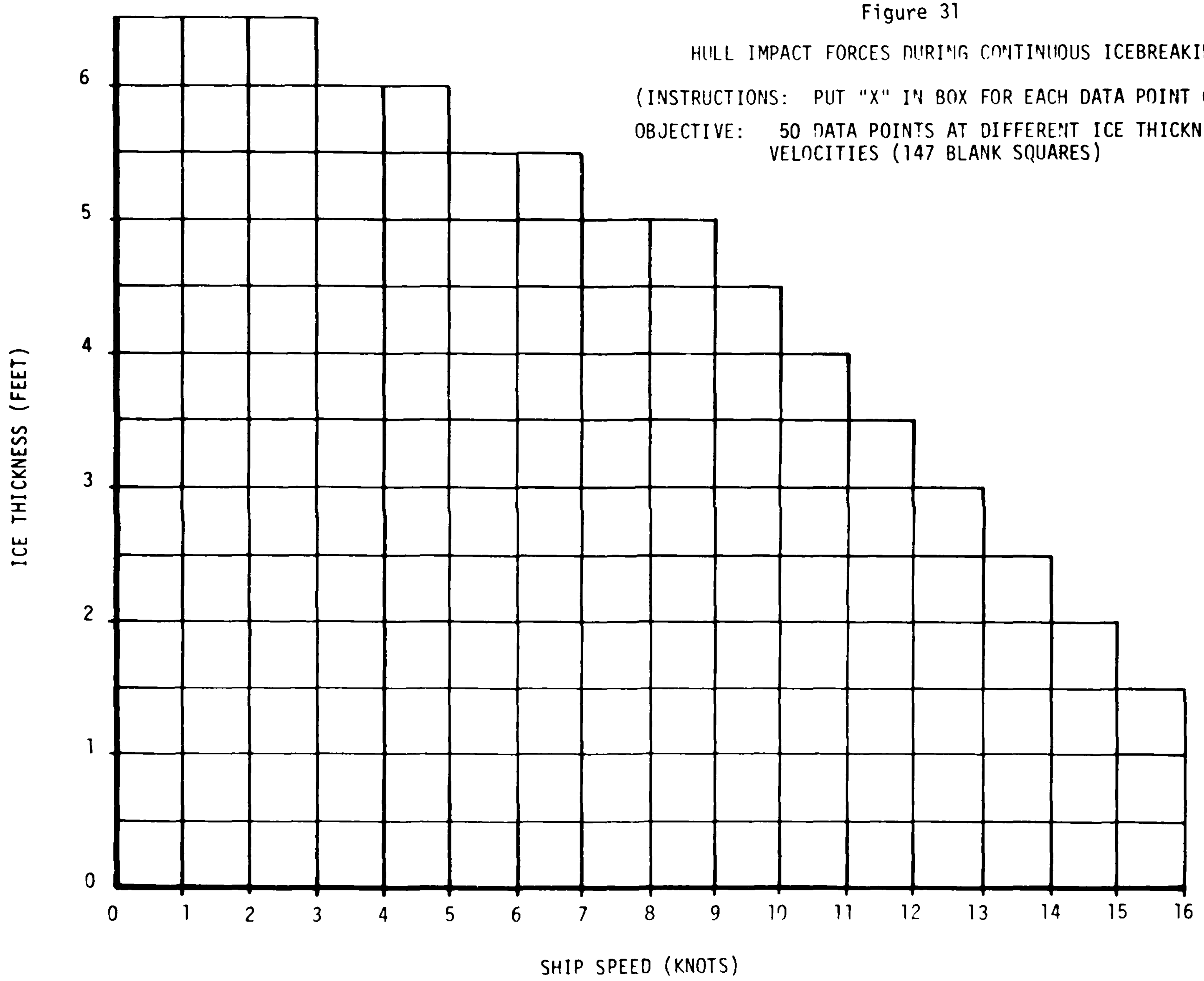


Figure 32

HULL IMPACT FORCES DURING RAMMING ICEBREAKING - LEVEL ICE

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED
PUT "O" IN BOX WHEN HEELING SYSTEM IN OPERATION)

OBJECTIVE: 10 DATA POINTS
(56 BLANK SQUARES)

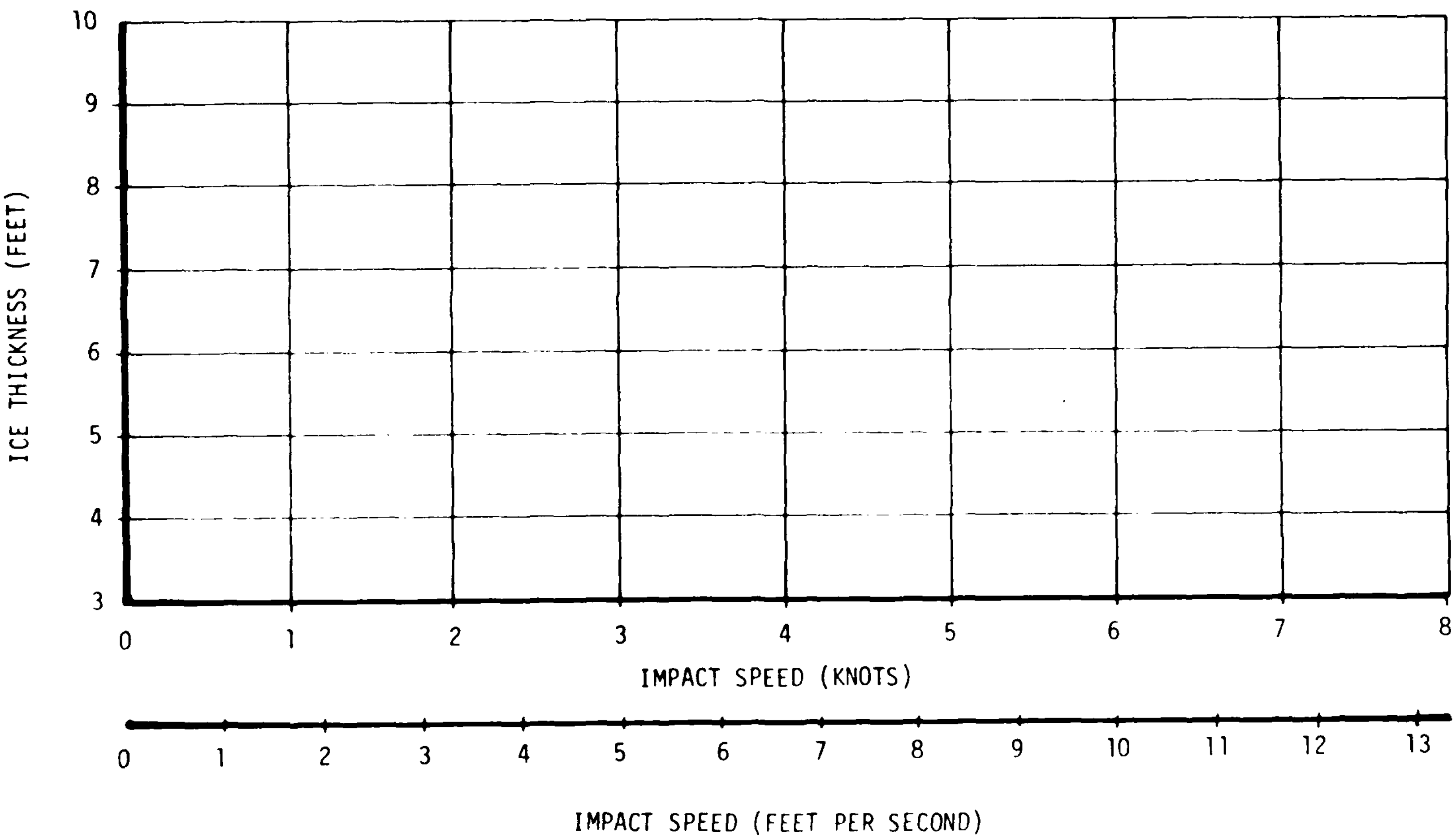


Figure 33

HULL IMPACT FORCES DURING RAMMING ICEBREAKING - PRESSURE RIDGES

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED
PUT "O" IN BOX WHEN HELLING SYSTEM IN OPERATION)

OBJECTIVE: 15 DATA POINTS
(40 BLANK SQUARES)

PRESS. RIDGE CLASS	Surface Expression HEIGHT (FT)	WIDTH (FT)	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8
5	8-	16-								
4	6-8	12-16								
3	4-6	8-12								
2	2-4	4-8								
1	0-2	0-4								

0 1 2 3 4 5 6 7 8

IMPACT SPEED (KNOTS)

0 1 2 3 4 5 6 7 8 9 10 11 12 13

IMPACT SPEED (FEET PER SECOND)

Figure 34

HULL IMPACT FORCES DURING MANEUVERING - TURNING CIRCLE

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED)

TEST	PORT	CENTER	STBD	RUDDER POSITION	ICE THICKNESS (FEET) 1	2	3	4	5	6
1	6,000 (D)	6,000 (D)	6,000 (D)	30° Right						
2	6,000 (D)	6,000 (D)	6,000 (D)	30° Left						
3	20,000 (GT)	20,000 (GT)	20,000 (GT)	30° Right						
4	20,000 (GT)	20,000 (GT)	20,000 (GT)	30° Left						

(D) - Diesel Electric

(GT) - Gas Turbine

Figure 35

HULL IMPACT FORCES DURING ICE FLOE COLLISION

(INSTRUCTIONS: PUT "X" IN BOX FOR EACH DATA POINT OBTAINED)

OBJECTIVE: 10 DATA POINTS
(300 BLANK SQUARES)

10	LARGER										
10	80 x 80										
10	40 x 40										
9	LARGER										
9	80 x 80										
9	40 x 40										
8	LARGER										
8	80 x 80										
8	40 x 40										
7	LARGER										
7	80 x 80										
7	40 x 40										
6	LARGER										
6	80 x 80										
6	40 x 40										
5	LARGER										
5	80 x 80										
5	40 x 40										
4	LARGER										
4	80 x 80										
4	40 x 40										
3	LARGER										
3	80 x 80										
3	40 x 40										
2	LARGER										
2	80 x 80										
2	40 x 40										
1	LARGER										
1	80 x 80										
1	40 x 40										
ICE THICKNESS (FEET)	FLOE SIZE (SURFACE AREA FT^2)										

0 1 2 3 4 5 6 7 8 9 10

SHIP SPEED (KNOTS)

TEST PLAN B-2

RUDDER ICE IMPACT

OBJECTIVE: To measure the magnitude and frequency of ice impact torque on the rudderstock of the POLAR STAR to evaluate the design and to provide data required by naval architects for future designs. This will also provide information concerning limits for operational purposes.

DESCRIPTION OF TESTS: Data will be recorded during Resistance Tests (A-1), Ramming Tests (A-2), and Maneuvering Tests (A-3). Data should also be recorded during backing with the rudder amidships.

TEST OUTPUT: Peak load vs. speed vs. direction of travel.

INSTRUMENTATION: The reaction torque in the rudderstock will be recorded along with the other measurements taken for the resistance, ramming, and maneuvering tests.

TEST PROCEDURE: These tests will be conducted following the same procedures outlined for the tests listed above.

SECTION C. MACHINERY PERFORMANCE

TEST PLAN C-1
PROPULSION SYSTEM CONTROLS

OBJECTIVE: To evaluate the control system for the main propulsion plant for all configurations of machinery in open water, continuous icebreaking, and ramming. Data collected will be useful for normal operation and maintenance of the plant.

DESCRIPTION OF TESTS: Three types of tests will be conducted. These are:

C-1a. Crash Reversal in Open Water.

C-1b. Continuous Icebreaking. These tests will be conducted as part of Tests A-1a.

C-1c. Ramming. These tests will be conducted in conjunction with Tests A-2.

During each of the three types of tests mentioned above, all engine combinations will be tested -- one diesel engine per shaft, two diesel engines per shaft, one gas turbine per shaft, one diesel engine on the center shaft, one diesel engine on each outboard shaft, two diesel engines on the center shaft, two diesel engines on the outboard shafts, one gas turbine on the center shaft, and one gas turbine on each outboard shaft.

TEST OUTPUT: Describe transient behavior of each measurement.

INSTRUMENTATION: The following variables will be measured:

Turbine RPM, N_1, N_2 ℄/Port (4 places)
Turbine Fuel Valve, ℄/Port (2 places)
Turbine Overload Gate (on/off) (3 places)

Diesel Engine RPM, ℄/Port (4 places)
Diesel Engine Rack, ℄/Port (2 places)

Bridge Cont. Position (3 places)
Prop. Pitch Command (3 places)
Prop. Hydraulic Pressure (3 places)
Prop. Pitch Angle Feedback (3 places)

Gen. Volts, AC, ℄/Port (4 places)
Gen. Amps, AC, ℄/Port (4 places)
Gen. Field Volts, DC, ℄/Port (4 places)
Gen. Field Amps, DC, ℄/Port (4 places)
Motor Volts, DC, ℄/Port (2 places)
Motor Amps, DC, ℄/Port (2 places)
Motor Field Volts, DC, ℄/Port (2 places)
Motor Field Amps, DC, ℄/Port (2 places)

TEST PROCEDURE:

1. For Test C-1a, Crash Reversal in Open Water, set up engine combination and go ahead at full power for that combination. When the ship has reached steady-state velocity, execute the crash reversal. Record the transients of each of the variables listed under instrumentation. Record drafts forward and aft.

2. For Test C-1b, Continuous Icebreaking, the test procedure of Tests A-1a will be followed. Record the transients of each of the variables listed above.

3. For Test C-1c, Ramming, the test procedure of Test A-2 will be followed. Record the transients of each of the variables listed above.

TEST PLAN C-2

PROPELLER ICE IMPACT AND ICE MILLING

OBJECTIVE: To measure the torque of the propeller shaft during ice impact and ice milling and to evaluate the effectiveness of the control system in reducing the loads on the propulsion system.

DESCRIPTION OF TESTS: Measurements will be recorded during Tests A-1, A-2, A-3, and B-1.

TEST OUTPUT:

(a) histogram of shaft RPM.

(b) histogram of propeller pitch command.

(c) histogram of propeller pitch angle (feedback).

(d) Depth of cut in ice, width of cut, blade advance.

INSTRUMENTATION: The variables listed in Test Plan C-1 will be measured, plus the following:

- shaft torque (4 places)
- shaft RPM (3 places)

TEST PROCEDURE:

Note: This procedure is unusually risky, both to the ship's propellers and machinery and to the ice team. As a result, the test will probably be begun at step 6 on those occasions where the circumstances are reasonably favorable.

1. Set up desired engine combination.

2. Back or go ahead in such a way as to get ice into the propellers.

3. Record data continuously during test.

4. When ice is encountered with propellers, continue operation until ice has cleared propeller.

5. Stop.

6. Ice team will attempt to locate ice blocks with milling marks and attempt to measure depth of cut, width of cut, and blade advance.

7. Measure temperature, salinity and density of ice.

8. Record draft, forward and aft.

TEST PLAN C-3

SHAFT TORSIONAL VIBRATIONS TESTS

OBJECTIVE: To measure the torsional vibrations propeller shafts during icebreaking operations.

DESCRIPTION OF TESTS: The shaft torsional vibration will be recorded during the following tests:

A-1a. Continuous Icebreaking Resistance Test
A-2. Ramming/Extraction Tests
A-3. Maneuvering Tests
C-2. Propeller Ice Impact and Ice Milling Tests

TEST OUTPUT: (a) frequency spectrum of shaft torque

(b) histogram of shaft torque

INSTRUMENTATION: The torsional vibration will be measured and recorded by strain gauging each of the propeller shafts. In addition, the following variables will be recorded:

- propeller RPM
- propeller pitch

The torsion measurements will be analyzed using a spectrum analyzer.

TEST PROCEDURE: Record vibrations during Tests A-1, A-2, A-3 and C-2.

TEST PLAN C-4

ENGINE COOLING AND RECIRCULATION

OBJECTIVE: To evaluate the distribution of cooling water between the various engines in each engine room.

DESCRIPTION OF TESTS: Data will be recorded during the open water transit to the test area and during transit in ice from one test area to another on an opportunity basis.

TEST OUTPUT: List of points measured and relative flow rates observed.

INSTRUMENTATION: In addition to the ship's installed instrumentation, 8 magnetically-held bi-metallic thermometers and one clamp-on type ultrasonic flowmeter will be used as necessary to evaluate the distribution of cooling water to major elements of the engineering plant.

MEASUREMENT POINTS:

Load	S.W. Supply*	S.W. Return*
Gen 1A	1-DSW-1A	1-DSW-3A
Gen 1B	1-DSW-1B	1-DSW-3B
Gen 2A	2-DSW-1A	2-DSW-3A
Gen 2B	2-DSW-1B	2-DSW-3B
Gen 3A	3-DSW-1A	3-DSW-3A
Gen 3B	3-DSW-1B	3-DSW-3B
SS Gen 1	DSW-1A	DSW-3A
SS Gen 2	DSW-1B	DSW-3B
SS Gen 3	DSW-1C	DSW-3C
Center Motor	2-MSW-16A	2-MSW-17A
Stbd. Motor	1-MSW-16A	1-MSW-17A
Port Motor	3-MSW-16A	3-MSW-17A

* Refer to Lockheed drawing 400 WAGB-4805-2 Rev. G, Sht. 2.

TEST PLAN C-5

MEASURED MILE SENSOR CALIBRATION

OBJECTIVE: To check the calibration of the propeller shaft torque and thrust sensors.

DESCRIPTION OF TESTS: Fourteen runs along a measured mile in the order indicated in Table 4 are required.

TEST OUTPUT: A table comparing the predicted and measured values of torque and thrust, and the error bounds of those figures.

INSTRUMENTATION: The following parameters will be measured and recorded for this test:

- ship's speed (from sightings of measured mile ranges)
- shaft thrust (3 shafts)
- shaft RPM (3 shafts)
- propeller pitch (3 shafts)
- ship's draft
- wind speed and direction
- wave height and direction
- predicted tidal current speed and direction (if applicable)
- courses steered
- motor volts (2 shafts)
- motor amps (2 shafts)

TEST PROCEDURE:

1. Enroute to the measured mile the instrumentation personnel warm up and check out their equipment. When the equipment is ready for test, they will advise the Bridge.

2. When all equipment and personnel are ready and the ship is on the measured mile track, the Conning Officer will apply the power estimated to be required to drive the ship at the desired speed.

3. When the ship is abeam of the measured mile ranges, a "mark" will be telephoned to the instrument center.

4. The Bridge personnel will measure the time to run between ranges with a stopwatch and will log this time, as well as wind speed and direction, course steered, wave height and direction and the predicted tidal current and direction.

5. After each run the ship will immediately come about and run the course in the reciprocal direction, changing power levels if indicated in Table 4. The data mentioned in (4.) above will be verified and recorded for each run.

6. After all runs are completed the equipment will be secured and the data analyzed. If the data is not satisfactory the test will be repeated.

Table 4

RUNS FOR MEASURED MILE SENSOR CALIBRATION

Order Of Runs	Estimated Speed (kts.)	Direction	Estimated Running Time (minutes)
1	9	→	6.7
2	9	←	6.7
3	11	→	5.5
4	11	←	5.5
5	13	→	4.6
6	13	←	4.6
7	15	→	4.0
8	15	←	4.0
9	13	→	4.6
10	13	←	4.6
11	11	→	5.5
12	11	←	5.5
13	9	→	6.7
14	9	←	6.7
			75.2*

* Plus time to turn at end of each run.

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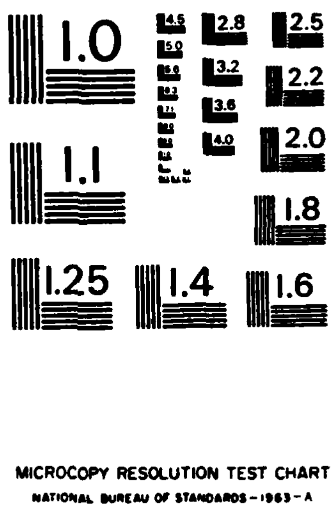
TEST PLANS(U) NAVAL OCEAN RESEARCH AND DEVELOPMENT
ACTIVITY NSTL STATION MS J P WELSH SEP 78

UNCLASSIFIED NORDA-22-VOL-2 MIPR-Z-51100-8-0003 F/G 13/10 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SECTION D. ENVIRONMENTAL DATA

TEST PLAN D-1

ICE PROPERTIES MEASUREMENT

1. Measurements of ice thickness, temperature, salinity, and density are planned for direct support of the CGC POLAR STAR ice trials. In addition, measurements of surface roughness, snow thickness, snow density, and pressure-ridge keel shape and depth are to be collected. Sea water temperature and salinity will be obtained on an opportunity basis. Detailed procedures are given in section VII.

2. Ice thickness will be measured using different techniques. The basic technique will be drilling and obtaining a direct tape measurement. The site for each thickness measurement will be selected by reference to a random number table. Table 5 is a sample data form for ice thickness measurement. The numbers in the left-most column were selected from a random number table and arrayed in ascending order. The starting point would be a convenient place on the ice forward of the ship. The numbers refer to the distance mark for each thickness measurement along a proposed icebreaker track from the starting point. The second technique is one of opportunity. It consists of either direct tape measurement or estimation of thickness of ice blocks resulting from passage of the icebreaker. The third technique is an impulse radar system. The system is helicopter mounted (or towed on the surface by a vehicle) and provides a record of ice thickness along the line. If this technique is successful, it will be utilized in two different ways: first, as a reconnaissance tool to help select sites, and second, as a tool to obtain many transects across a chosen test site immediately prior to testing. The forth technique is specifically directed toward measurement of the thickness of pressure ridges and hummocks. This technique makes use of sonar. The transducer of a specially designed (candlestick sonar) unit is lowered through a hole in the ice adjacent to the ridge or hummock. The sonar indicates the distance to the nearest reflector in the horizontal plane determined by the transducer's vertical position. The reference point for vertical control is the water line in the hole in the ice. By varying the vertical position of the transducer, a profile can be constructed. This system is omnidirectional in the horizontal plane. A second sonar system which is direction controlled in the horizontal plane may be used conditions permitting.

3. The temperature of the ice will be measured using thermometers, thermocouples, and thermisters. A specially designed system using ten thermisters placed one centimeter apart in the vertical will be used for detailed profiles of the top ten centimeters of ice. The thermometers will be used for direct measurement in ice cores. In addition, a direct reading themocouple probe will be used for

ice core temperatures. Two sampling schemes will be considered for constructing vertical ice temperature profiles. The first scheme will be to select ten measurement points by reference to a random number table. The starting point will be the ice/air interface. Each random number will determine the vertical distance along an ice core where a temperature measurement is to be made. This data will be used to calculate summary descriptive statistics for the temperature of the ice and for calculations of brine volume. Results of the brine volume calculations will be used for inferring strength of the ice. The second scheme will be to obtain one temperature measurement for each ten centimeter section of ice core. This data will be used for reference to the routine CRREL (Cold Regions Research and Engineering Laboratory) procedure.

4. The ice density will be obtained by selecting random sections of ice core. The section will be measured (diameter and height) and weighed on a triple beam balance. The second scheme will be one of opportunity. When manageable size pieces of ice are found they will be measured and weighed.

5. Strength will be obtained indirectly. Temperature and salinity will be measured from selected ice core (taken in the proposed test area) and brine volume calculated. The relationship between strength and brine volume will be assumed to follow the postulated behavior presented by Assur (1958).

6. Surface roughness will be obtained using plane table mapping methods. The product is a topographic map of the ice and snow surface. Snow thickness and density will be measured and the map annotated with this information. This may be useful for assessing the snow's contribution to friction.

7. The data described above will be collected by three teams: A Flag Team, a Thickness Team and a Core Team. The duties of these teams are shown in Table 6.

TABLE 5
ICE THICKNESS

DATE: TIME:

LOCATION:

WX: (CIRCLE) CAVU OVC SNOWING AIR TEMP.

WIND SPEED________KTS. WIND DIRECTION_______°T

DISTANCE TO SAMPLING POINT	THICKNESS ICE	THICKNESS SNOW	COMMENTS:
12			
37			
43			
61			
77			
86			
92			
99			
109			
123			
254			
258			
375			
487			
513			
538			
580			
641			
685			
730			
786			
832			
842			
923			
962			

Units of
Distance

(Check One)

Centimeters
Meters
Kilometers

TABLE 6

ICE TEAM/TEST TYPE MATRIX
(ASSIGNMENT OF DUTIES)

TEST TYPE	FLAG TEAM	THICKNESS TEAM	CORE TEAM
Continuous icebreaking or ramming in level ice or maneuvering.	(1) Ships draft, fwd and aft. (2) Set flags out as directed. (3) Obtain ice thickness with hand auger. (4) Recover flags after test run.	(1) Tow ice radar with ATV over designated track. (2) Obtain snow cover and thickness data. (3) Search for ice milled by propeller after test run.	(1) Obtain temperature profile data. (2) Obtain ice densities. (3) Obtain ice cores. (4) Obtain meteorological data.
Ramming in pressure ridges.	(1) Obtain ship's draft, fwd and aft. (2) Set flags out as directed. (3) Obtain ice thickness on both sides of ridge with auger. (4) Recover flags after test run.	(1) Make topographic map of ridge using plane table, alidade, and rod. (2) Determine horizontal impact angle of ship. (3) Use sonar to measure draft of ridge and keel profile.	same as above.

TEST PLAN D-2

METEOROLOGICAL DATA

1. The Ice Core Team will be responsible for obtaining the meteorological data. The data of interest consists of wind speed and direction, dry-bulb air temperature, barometric pressure, cloud cover, and precipitation.

2. The primary method for obtaining and recording the wind and temperature data will be automated devices that will be set up on the ice for operation during the ship testing. If this equipment fails or is lost, the data will be recorded manually.

3. The cloud cover and precipitation data will, of course, be recorded manually.

SECTION E. PHOTOGRAPHIC DOCUMENTATION

Photographic needs are based on three requirements. The first is the development of a motion picture film documenting the ice-breaking voyage of the POLAR STAR and to highlight special aspects of the test program. Movies of this type exist for some of the WIND class voyages (NORTHWIND 1969-70 winter voyage). Motion pictures showing ramming and maneuvering operations will also be of value for use in technical analysis. The second requirement is to obtain black and white photographs for use in the technical report of the POLAR STAR tests, highlighting important technical aspects of the test program. The third is to obtain slides which will be of great value for briefings and technical presentations.

In order to insure that the desired coverage is in fact obtained, the Test Director will maintain a detailed log of the contents of each roll of film. Photographers will be issued numbered rolls of film on a daily basis and will return the film and make appropriate entries in the log at the end of each day. In addition, when the photographer draws his film, he will be issued a card with his photographic assignment on it.

TEST PLAN E
PHOTOGRAPHIC DOCUMENTATION

OBJECTIVE: To provide photographic documentation on technical aspects of the trials.

DESCRIPTION OF PICTURES TO BE TAKEN:

Title	Motion Pictures (Color)	Still Pictures (Color Slides)	Still Pictures (B & W Prints)
Installation of Instrumentation and Equipment			
1. Installation of hull strain gages		☐	☐
2. Installation of permanent propeller shaft torque instrumentation		☐	☐
3. Installation of propeller shaft thrust instrumentation		☐	☐
4. Instrument room, general view		☐	☐
5. Calibration of hull strain gages	☐	☐	☐
6. Calibration of rudderstock strain gages		☐	☐
7. Close-up of flag observer sights		☐	☐
8. Close-up of doppler radar antenna mounted in bracket		☐	☐
9. Doppler radar plus telemetry equipment mounted on tripod on the ice.		☐	☐

Title	Motion Pictures (Color)	Still Pictures (Color Slides)	Still Pictures (B & W Prints)
Installation of Instrumentation and Equipment (Cont'd.)			
10. Close-up of propeller shaft RPM pickups		☐	☐
11. Temporary shaft torque instrumentation			☐
Open Water Operations			
1. View from helicopter, bow, side and quarter, high and low elevations	☐	☐	☐
2. Bow wave at various ship speeds (from helicopter)	☐	☐	☐
3. Sharp turns (vertical from helicopter)	☐	☐	☐
4. From full ahead to crash astern (quarter from helicopter)	☐	☐	☐
Continuous Icebreaking Test			
1. View of bow from ice	☐	☐	☐
2. View of ice field ahead, showing speed flags	☐	☐	☐
3. View of ship's side	☐	☐	☐
4. View of ice field astern	☐	☐	☐
5. View from helicopter	☐	☐	☐
6. View from aloft station	☐	☐	☐

Title	Motion Pictures (Color)	Still Pictures (Color Slides)	(B & W Prints)
Heeling System Tests			
1. View from dead ahead, on the ice	☐	☐	☐
Ramming in Uniformly Thick Ice			
1. View of bow	☐	☐	☐
2. View of ice field ahead	☐	☐	☐
3. View of ship side	☐	☐	☐
4. View of ice field astern	☐	☐	☐
5. View from helicopter	☐	☐	☐
Ramming A Pressure Ridge			
1. View of bow	☐	☐	☐
2. View of ice field ahead	☐	☐	☐
3. View of ship side	☐	☐	☐
4. View of ice field astern	☐	☐	☐
5. View from helicopter	☐	☐	☐
Maneuvering Tests			
1. View of bow	☐	☐	☐
2. View of ice field ahead	☐	☐	☐
3. View of ship side	☐	☐	☐
4. View of ice field astern	☐	☐	☐
5. View from helicopter (vertical)	☐	☐	☐

Title	Motion Pictures (Color)	Still Pictures (Color Slides)	Still Pictures (B & W Prints)
Hull Friction Tests			
1. View of apparatus, still	☐	☐	☐
2. View of ice piece in apparatus	☐	☐	☐
3. View of apparatus in operation	☐	☐	☐
4. View of force blocks	☐	☐	☐
Environmental Data Collection			
1. Ice coring	☐	☐	☐
2. Measuring ice thickness	☐	☐	☐
3. Operations from ATV	☐	☐	☐
4. View of snow storm	☐	☐	☐
5. View of night operations	☐	☐	☐
6. View of ice density measurements	☐	☐	☐
7. View of mapping pressure ridge from the ice	☐	☐	☐
8. View of pressure ridge mapping (from helicopter)	☐	☐	☐
General Internal and External Views of Ship			
1. Side view from ice	☐	☐	
2. Bow-on view from ice	☐	☐	
3. Quarter view from ice	☐	☐	
4. Bow view from air	☐	☐	

Title	Motion Pictures (Color)	Still Pictures (Color Slides)	Still Pictures (B & W Prints)
General Internal and External Views of Ship (Cont'd.)			
5. Quarter view from air	☐	☐	
6. Bridge interior	☐	☐	
7. View of ice from bridge	☐	☐	
8. View of ice from aloft section	☐	☐	
9. View of interior of aloft section	☐	☐	
10. View of typical stateroom	☐	☐	
11. View of wardroom	☐	☐	
12. View of crew's mess and rec rooms	☐	☐	
13. View of engine room control center	☐	☐	
14. View of helicopter in the air	☐	☐	
15. View of helicopter hovering above flight deck	☐	☐	
16. View of interior of hangar with helicopters inside	☐	☐	
17. View of ship at night in the ice	☐	☐	

I. Documentation of Test Data

1. General

All test data will be labeled with a run number or a data point number and will be stored in containers marked with this number. These numbers will be established as follows:

a. The first two or three digits will always be the Julian date on which the data was collected, e.g., 1 FEB = 32 and 1 MAY = 121.

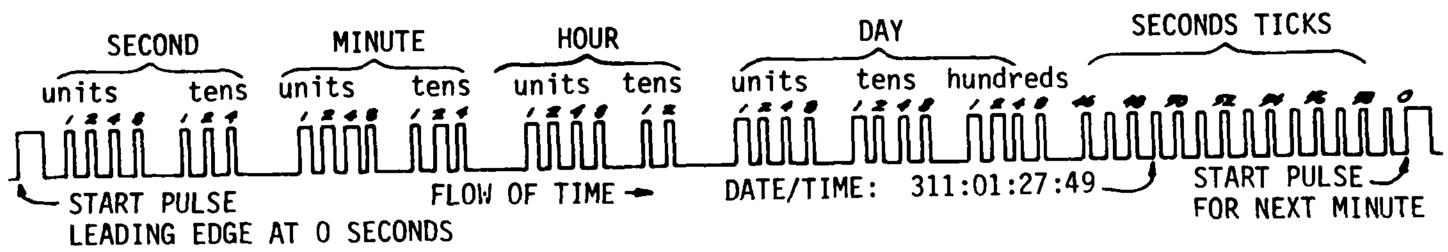
b. The next digit will indicate which run of those performed on a particular date. This digit will be separated from the Julian date by a hyphen, e.g., the second run performed on 1 FEB would have a run number of 32-2.

c. Whenever possible, two or more data points will be obtained during a run. These data points will be assigned numbers in sequence. This number will be added to the run number using another hyphen. Thus, the third data point of the second run on 1 FEB would have a data point number of 32-2-3.

Ice team and bridge data sheets will be used and annotated in such a way that, to the maximum extent practical, the data can be physically segregated by run number or (preferably) data point number.

The magnetic tapes will be marked with the run numbers that they contain. The Instrument Center recorder charts will be marked with the data points that have been assigned. However, the ice-thickness-radar recorder charts need only be marked with the run number. The ice/hull friction-machine recorder charts will be labeled with run numbers as above, but assigned independently of the above numbers (these charts can be identified as to their contents by the size of the paper).

The date and time will be recorded in code on the magnetic tape. When the data is reproduced on the oscillograph recorders, the time code trace will appear as shown in Figure 35. There is a pulse every second except for spaces in the time code; the leading edge of a pulse is the reference. The first pulse of each minute is one second wide. The width of the following pulses are



TYPICAL TIME CODE TRACE

FIGURE 36 EXAMPLE OF THE TIME CODE TRACE

either 1/4-second or 1/2-second. The date and time are coded in binary as follows:

1/4-sec. pulse width = 0

1/2-sec. pulse width = 1

Reading the time code trace is explained in detail in Figure 36. This example is also reproduced on Data Sheets 1 - 16.

2. Ship Performance Data

The raw data collected during the test program will be processed into the form required for analysis through the use of a hierarchy of logs and worksheets. The first step will be to "read" the chart recordings of the instrument outputs and transcribe the desired measurements onto worksheets. This "reading" will require a certain amount of judgement in that peak values, averages and the existence of either steady-state or anomalous conditions must be determined. Alternately, a random sampling plan may be used to sample the thrust and torque data. These worksheets appear in the following section as Data Sheets 1 - 16. Another source of raw data will be the Bridge Logsheet, shown as Data Sheet 17 in section V.

The next step is to organize the data contained in the above first-level worksheets in a way convenient for further examination and calculation. This is done by transcribing the data from the first-level worksheets onto various second-level worksheets. Whereas the first-level worksheets are oriented toward the arrangement of the recording system, the second-level worksheets are oriented toward a particular test, such as continuous icebreaking resistance. The second-level worksheets appear as Data Sheets 18 to 32 in section VI and Figure 37.

Ultimately, the data from the second-level worksheets will be summarized in tables, graphs and histograms.

Section VII, Data Sheets 33 to 42 and Figures 38 to 47, contains ice data collection procedures.

IV. FIRST LEVEL WORKSHEETS

IV. FIRST LEVEL WORKSHEETS

DATA SHEET 1

FIRST-LEVEL WORKSHEET FOR GULTON RECORDER #1, PASS #1

Today's Date__________ Data Point NR________

Your Name______________________________________

Channel Number	Channel Contents	Sketches
1	date/time	
2	ctr brg controller	
3	ctr prop pitch cmd	
4	ctr prop pitch F/B	
5	ctr Ahd Hy. Pr.	
6	doppler speed	
7	fwd speed sw	
8	aft speed sw	
Event	ctr G.T. O/L gate	

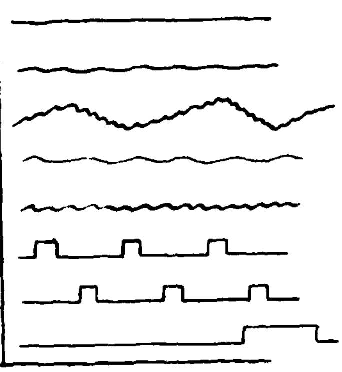


Chart Paper Speed: 6 in/min./________in/sec.
mm/sec.
div/sec.

Time at start of data point_______ End_________

Ctr Brg Controller [(____x 2)-1] x 100 = _____% F/R

Ctr Prop Pitch Cmd _____ x 100 = _____% F/R

Ctr Pitch F/B _____ x 100 = _____% F/R

Ctr Ahd Hy. Pr. _____ x 500 = _____ psid

Doppler Speed _____ x 20 = _____ FPS

Fwd Speed SW _____ Sec. $\frac{FS}{T}$ = _____ FPS

Aft Speed SW _____ Sec. $\frac{FS}{T}$ = _____ FPS

Ctr G.T. O/L Gate: Time On:______ Time Off:______

DATA SHEET 1 (Continued)

Max ctr prop pitch cmd _______ x 100 = _______% F/R

Min ctr prop pitch cmd _______ x 100 = _______% F/R

Max ctr prop pitch F/B _______ x 100 = _______% F/R

Min ctr prop pitch F/B _______ x 100 = _______% F/R

Parameter	Pk at Overshoot	Pk at Undershoot	Cycles of Ringing
Ctr brg cont.			
Ctr prop pitch cmd			
Ctr prop pitch F/B			
Ahd Hy. Pr.			
Ctr G.T. O/L gate			

NOTES:

1. "FS" means flag spacing in feet.
2. Center of each graph is zero. With time running from left to right, signals above center are ahead, starboard, up or positive; below are astern, port, down or negative. The range of each signal is ±1.00 inch.
3. Use a straightedge to strike the average values for channels 2-6.
4. Event marker in rest position means O/L gate is OFF.

COMMENTS:

DATA SHEET 2

FIRST-LEVEL WORKSHEET FOR GULTON RECORDER #1, PASS #2

Today's Date ________ Data Point NR ______

Your Name ______________________________

Channel Number	Channel Contents	Sketches
1	stbd brg controller	
2	date/time	
3	stbd prop pitch cmd	
4	stbd prop pitch F/B	
5	stbd Ahd Hy. Pr.	
6	rudder angle	
7	roll angle	
8	pitch angle	
Event	stbd G.T. O/L gate	

Chart
Paper Speed: 6 in/min./________ in/sec.
mm/sec.
div/sec.

Time at start of data point____ End_____

Stbd Brg cont. [(_____ x 2)-1] x 100 = _____% F/R

Stbd Prop Pitch Cmd _____ x 100 = _____% F/R

Stbd Prop Pitch F/B _____ x 100 = _____% F/R

Stbd Ahd Hy. Pr. _____ x 500 = _____ psid

Rudder Angle _____ x 30 = _____° P/S

Roll Angle _____ x 40 = _____° P/S

Pitch Angle _____ x 20 = _____° U/D

Stbd. G.T. O/L Gate: Time On:_____ Time Off _____

DATA SHEET 2 (Continued)

Max stbd prop pitch cmd ______ x 100 = ______% F/R

Min stbd prop pitch cmd ______ x 100 = ______% F/R

Max stbd prop pitch F/B ______ x 100 = ______% F/R

Min stbd prop pitch F/B ______ x 100 = ______% F/R

Max rudder angle ______ x 30 = ______° P/S

Min rudder angle ______ x 30 = ______° P/S

Max roll angle ______ x 40 = ______° P/S

Max pitch up angle ______ x 20 = ______°

Max pitch down angle ______ x 20 = ______°

Parameter	Pk at Overshoot	Pk at Undershoot	Cycles of Ringing
Stbd brg cont.			
Stbd prop pitch cmd			
Stbd prop pitch F/B			
Ahd Hy. Pr.			
Stbd G.T. O/L gate			

NOTES:

1. Center of each graph is zero. With time running from left to right, signals above center are ahead, starboard, up or positive; below are astern, port, down or negative. The range of each signal is ±1.00 inch.
2. Use a straightedge to strike the average values for channels 3-8.
3. Event marker in rest position means O/L gate is OFF.

COMMENTS:

DATA SHEET 3

FIRST-LEVEL WORKSHEET FOR GULTON RECORDER #1, PASS #3

Today's Date ________ Date Point NR ______

Your Name ________________________________

Channel Number	Channel Contents	Sketches
1	port brg cont.	
2	port prop pitch cmd	
3	date/time	
4	port prop pitch F/B	
5	port Ahd Hy. Pr.	
6	surge acceleration	
7	engine RPM (3B)	
8	throttle (2A)	
Event	port G.T. O/L Gate	

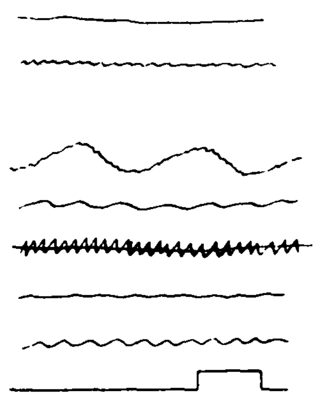


Chart
Paper Speed: 6 in/min./______in/sec.
mm/sec.
div/sec.

Time at start of data point ______ End_______

Port brg cont. [(______x 2)-1] x 100 = _____% F/R

Port prop pitch cmd ______ x 100 = _____% F/R

Port prop pitch F/B ______ x 100 = _____% F/R

Port Ahd Hy. Pr. ______ x 500 = _____ psid

Engine RPM (3B) ______ x1750 = _____ RPM

Throttle (2A) ______ x 100 = _____% F/R

Port G.T. O/L Gate: Time On: _____Time Off: _____

DATA SHEET 3 (Continued)

Max. port prop pitch cmd _____ x 100 = _____% F/R

Min. port prop pitch cmd _____ x 100 = _____% F/R

Max. port prop pitch F/B _____ x 100 = _____% F/R

Min. port prop pitch F/B _____ x 100 = _____% F/R

Max surge acceleration _____ x (   ) = _____ G's

Avg. surge acceleration _____ x (   ) = _____ G's

Max. surge deceleration _____ x (   ) = _____ G's

Avg. surge deceleration _____ x (   ) = _____ G's

Parameter	Pk at Overshoot	Pk at Undershoot	Cycles of Ringing
Port brg cont.			
Port prop pitch cmd			
Port prop pitch F/B			
Port Ahd Hy. Pr.			
Throttle (2A)			
Engine RPM (3B)			
Port G.T. O/L gate			

NOTES:

1. Center of each graph is zero. With time running from left to right, signals above center are ahead, starboard, up or positive; below are astern, port, down or negative. The range of each signal is ±1.00 inch.
2. Use a straightedge to strike the average values of channels 1, 2, 4-8.
3. Event marker in rest position means O/L gate is OFF.

COMMENTS:

DATA SHEET 4

FIRST-LEVEL WORKSHEET FOR GULTON RECORDER #1, PASS #4

Today's Date __________ Data Point NR ______

Your Name

Channel Number	Channel Contents	Sketches
1	ctr G.T.N_1	
2	ctr G.T.N_2	
3	port mtr fld volts	ac signal
4	date/time	
5	port G.T.N_1	
6	port G.T.N_2	
7	port mtr. fld amps	ac signal
8	pitch acceleration	
Event	not used	

Chart Paper Speed: 6 in/min.______in/sec.
mm/sec.
div/sec.

Time at start of data point______ End______

Ctr. G.T.N_1	_____	x	7,428 =	_____	RPM
Ctr. G.T.N_2	_____	x	11,428 =	_____	RPM
Port motor field volts	_____	x	211	_____	volts
Port G.T.N_1	_____	x	6,571 =	_____	RPM
Port G.T.N_2	_____	x	10,875 =	_____	RPM
Port motor field amps	_____	x	90 =	_____	amps

DATA SHEET 4 (Continued)

Max. ctr G.T.N_1 _____ x 10,000 = _____ RPM

Min. ctr G.T.N_2 _____ x 10,000 = _____ RPM

Max. ctr G.T.N_2 _____ x 10,000 = _____ RPM

Min. ctr G.T.N_2 _____ x 10,000 = _____ RPM

Max port G.T.N_1 _____ x 10,000 = _____ RPM

Min port G.T.N_1 _____ x 10,000 = _____ RPM

Max port G.T.N_2 _____ x 10,000 = _____ RPM

Min port G.T.N_2 _____ x 10,000 = _____ RPM

Max pitch up acceleration _____ x 0.1 = _____ G's

Avg. pitch up acceleration _____ x 0.1 = _____ G's

Max pitch down acceleration _____ x 0.1 = _____ G's

Avg. pitch down acceleration _____ x 0.1 = _____ G's

Parameter	Pk at Overshoot	Pk at Undershoot	Cycles of Ringing
Ctr G.T. N_1			
Ctr G.T. N_2			
Port G.T. N_1			
Port G.T. N_2			

NOTES:

1. Center of each graph is zero. With time running from left to right, signals above center are ahead, starboard, up or positive; below are astern, port, down or negative. The range of each signal is ±1.00 inch.

2. Use a straightedge to strike the average values for channels 1-3, and 5-7.

COMMENTS:

DATA SHEET 5

FIRST-LEVEL WORKSHEET FOR GULTON RECORDER #2, PASS #1

Today's Date_______ Data Point NR_____

Your Name

Channel Number	Channel Contents	Sketches
1	date/time	
2	ship's heading	dc level
3	ctr shft RPM	
4	stbd G.T. S/G beam	
5	Gen (2A) field volts	dc level
6	Gen (2A) field amps	dc level
7	ctr motor field volts	dc level
8	ctr motor field amps	dc level
Event	not used	

Chart
Paper Speed: 6 in/min./______in/sec.
mm/sec.
div/sec.

Time at start of data point_____ End_______

Ship's heading (±____ x 180)		+	360	=_____	°T
Ctr shft RPM	_____	x	180	=_____	RPM
Gen (2A) field volts	_____	x	211	=_____	volts
Gen (2A) field amps	_____	x	90	=_____	amps
Ctr motor field volts	_____	x	211	=_____	volts
Cts motor field amps	_____	x	90	=_____	amps

DATA SHEET 5 (Continued)

Signals	Pk at Undershoot	Pk at Overshoot	Cycles of Ringing	Other
Gen (2A) fld volts				
Gen (2A) fld amps				
Ctr motor fld volts				
Ctr motor fld amps				

NOTES:

1. Center of each graph is zero. With time running from left to right, signals above center are ahead, starboard, up or positive; below are astern, port, down or negative. The range of each signal is ±1.00 inch.
2. Describe observed transient conditions.

COMMENTS:

DATA SHEET 6

FIRST-LEVEL WORKSHEET FOR GULTON RECORDER #2, PASS #2

Today's Date________ Data Point NR______

Your Name________________________________

Channel Number	Channel Contents	Sketches
1	engine rpm (3A)	dc level
2	date/time	
3	engine throttle (3A)	dc level
4	Gen volts (3A)	ac - measure peak
5	stbd shft RPM	
6	engine rpm (2A)	dc level
7	Gen (3A) field volts	dc level
8	Gen (3A) field amps	dc level
Event	not used	

Chart Paper Speed: 6 in/min./_______in/sec.
mm/sec.
div/sec.

Time at start of data point ________ End______

Engine RPM (3A)	_____	x	2,875	=	_____	RPM
Engine Throttle (3A)	_____	x	100	=	_____	%
Gen Volts (3A) (peak)	_____	x	1,200	=	_____	volts
Stbd shft RPM	_____	x	180	=	_____	RPM
Engine RPM (2A)	_____	x	2,875	=	_____	RPM
Gen (3A) field volts	_____	x	211	=	_____	volts
Gen (3A) field amps	_____	x	90	=	_____	amps

DATA SHEET 6 (Continued)

Signals	Pk at Undershoot	Pk at Overshoot	Cycles of Ringing	Other
Engine (3A) RPM				
Engine (3A) Throttle				
Gen (3A) volts				
Stbd shft RPM				
Engine (2A) RPM				
Gen (3A) fld volts				
Gen (3A) fld amps				

NOTES:

1. Center of each graph is zero. With time running from left to right, signals above center are ahead, starboard, up or positive: below are astern, port, down or negative. The range of each signal is ±1.00 inch.
2. Describe observed transient conditions.

COMMENTS:

DATA SHEET 7

FIRST-LEVEL WORKSHEET FOR GULTON RECORDER #2, PASS #3

Today's Date_______ Data Point NR________

Your Name________________________________

Channel Number	Channel Contents	Sketches
1	engine RPM (2B)	dc level
2	port shft RPM	
3	date/time	
4	ctr. G.T. S/G beam	
5	stbd G.T. S/G Long.	
6	Gen volts (3B)	dc level
7	Gen field volts (2B)	ac signal
8	Gen field amps (2B)	ac signal
Event	not used	

Chart Paper Speed: 6 in/min./_______in/sec.
mm/sec.
div/sec.

Time at start of data point ________ End________

Engine RPM (2B)	_____	x 2,875 =	_____	RPM
Port shft RPM	_____	x 180 =	_____	RPM
Gen volts (3B) (peak)	_____	x 1,200 =	_____	volts
Gen field volts (2B)	_____	x 211 =	_____	volts
Gen field amps (2B)	_____	x 75 =	_____	amps

DATA SHEET 7 (Continued)

Signals	Pk at Undershoot	Pk at Overshoot	Cycles of Ringing	Other
Engine (2B) RPM				
Port shft RPM				
Gen (3B) volts				
Gen (2B) fld volts				
Gen (2B) fld amps				

NOTES:

1. Center of each graph is zero. With time running from left to right, signals above center are ahead, starboard, up or positive; below are astern, port, down or negative. The range of each signal is ±1.00 inch.
2. Describe observed transient conditions.

COMMENTS:

DATA SHEET 8

FIRST-LEVEL WORKSHEET FOR GULTON RECORDER #2, PASS #4

Today's Date________ Data Point NR_____

Your Name______________________________

Channel Number	Channel Contents	Sketches
1	Gen (3B) field volts	dc level
2	Gen (3B) field amps	dc level
3	ctr. Long. vib	ac signal
4	date/time	
5	stbd long. vib	ac signal
6	ctr G.T. S/G long	
7	not used	
8	not used	
Event	not used	

Chart
Paper Speed: 6 in/min./______in/sec.
mm/sec.
div/sec.

Time at start of data point_______ End_____

Gen (3B) field volts _____ x 211 = _____volts

Gen (3B) field amps _____ x 90 = _____amps

Center longitudinal vib_____ x 79 = _____mils

Stbd longitudinal vib _____ x 77 = _____mils

DATA SHEET 8 (Continued)

Signals	Pk at Undershoot	Pk at Overshoot	Cycles of Ringing	Other
Gen (3B) fld volts				
Gen (3B) fld amps				

NOTES:

1. Center of each graph is zero. With time running from left to right, signals above center are ahead, starboard, up or positive; below are astern, port, down or negative. The range of each signal is ±1.00 inch.
2. Describe observed transient conditions.

COMMENTS:

DATA SHEET 9

FIRST-LEVEL WORKSHEET FOR OSCILLOGRAPH #1, PASS #1

Today's Date__________ Data Point NR_________

Your Name_______________________________________

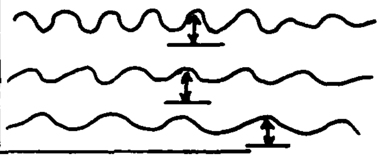
Channel Number	Channel Contents	Sketches
1	date/time	
2	SG 11	
3	SG 12	"
4	SG 13	"
5	SG 14	"
6	SG 15	"
7	SG 16	"
8	ctr shaft torque #1 (ECC)	
9	ctr thrust fwd #1	
10	ctr shaft torque #2 (AUX 4)	

Chart Paper Speed: 12 in/sec./_______in/sec.
mm/sec.
div/sec.

Time at start of data point________ End________

Avg ctr shaft torque #1 _____ x 1,640,000 = _____ft-lbs

Max ctr shaft torque #1 _____ x 1,640,000 = _____ft-lbs

Min ctr shaft torque #1 _____ x 1,640,000 = _____ft-lbs

Avg ctr shaft torque #2 _____ x 1,270,000 = _____ft-lbs

Max ctr shaft torque #2 _____ x 1,270,000 = _____ft-lbs

Min ctr shaft torque #2 _____ x 1,270,000 = _____ft-lbs

Avg ctr thrust fwd #1 _____ x 100,000 = _____lbs

Max ctr thrust fwd #1 _____ x 100,000 = _____lbs

Min ctr thrust fwd #1 _____ x 100,000 = _____lbs

DATA SHEET 9 (Continued)

TIME	SG 11	SG 12	SG 13	SG 14	SG 15	SG 16

NOTES:

1. Use a straightedge to strike an average value for 8, 9 and 10.
2. Measure signals to 0.05 inches or better.
3. Select the ten largest impact signals from the strain gage oscillograph traces. Record the time of occurence of each of the selected impacts, and record the magnitude of all of the strain gage signals for each of the selected impacts.

COMMENTS:

DATA SHEET 10

FIRST-LEVEL WORKSHEET FOR OSCILLOGRAPH #1, PASS #2

Today's Date__________ Data Point NR_________

Your Name____

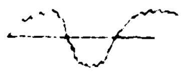
Channel Number	Channel Contents	Sketches
1	SG 21	
2	date/time	
3	SG 22	same as 1
4	SG 23	same as 1
5	SG 24	same as 1
6	SG 25	same as 1
7	SG 26	same as 1
8	rudderstock torque	
9	not used	
10	stbd shaft torque	

Chart
Paper Speed: 12 in/sec./________in/sec.
mm/sec.
div/sec.

Time at start of data point______ End________

Pk rudder torque (pos) _____ x 180,000 = _____ft-lbs

Pk rudder torque (neg) _____ x 180,000 = _____ft-lbs

Avg stbd shaft torque _____ x 1,500,000 = _____ft lbs.

Max stbd shaft torque _____ x 1,500,000 = _____ft lbs.

Min stbd shaft torque _____ x 1,500,000 = _____ft lbs.

DATA SHEET 10 (Continued)

TIME	SG 21	SG 22	SG 23	SG 24	SG 25	SG 26

RUDDERSTOCK TORQUE		
Magnitude	Port	Stbd

COMMENTS:

NOTES:

1. Use a straightedge to strike an average value for channel 10.
2. Measure signals to 0.05 inches or better.
3. Transcribe the times of occurrence of strain gage peaks from Data Sheet #9 onto this worksheet, then measure and record the signals occurring at the same time on this data.

DATA SHEET 11

FIRST-LEVEL WORKSHEET FOR OSCILLOGRAPH #1, PASS #3

Today's Date_________ Data Point NR________

Your Name____________________________________

Channel Number	Channel Contents	Sketches
1	SG 31	
2	SG 32	same
3	date/time	
4	SG 33	same as 1
5	SG 34	same as 1
6	SG 35	same as 1
7	SG 36	same as 1
8	thrust, port, fwd, #1	
9	thrust, port, fwd, #2	same
10	NSRDC Clock	

Chart
Paper Speed: 12 in/sec./_______in/sec.
mm/sec.
div/sec.

Time at start of data point______ End________

Avg thrust, port,fwd #1 _____ x 100,000 = _____ lbs

Max thrust, port,fwd #1 _____ x 100,000 = _____ lbs

Min thrust, port,fwd #1 _____ x 100,000 = _____ lbs

Avg thrust, port,fwd #2 _____ x 100,000 = _____ lbs

Max thrust, port,fwd #2 _____ x 100,000 = _____ lbs

Min thrust, port,fwd #2 _____ x 100,000 = _____ lbs

DATA SHEET 11 (Continued)

TIME	SG 31	SG 32	SG 33	SG 34	SG 35	SG 36

NOTES:

1. Use a straightedge to strike the average values for 8 and 9.
2. Measure the signals to 0.05 inches or better.
3. Transcribe the times of occurrences of strain gage peaks from Data Sheet #9 onto this worksheet. Then measure and record the signals occurring at the same time on this data.

COMMENTS:

DATA SHEET 12

FIRST-LEVEL WORKSHEET FOR OSCILLOGRAPH #1, PASS #4

Today's Date__________ Data Point NR_________

Your Name____

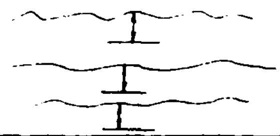
Channel Number	Channel Contents	Sketches
1	SG 41	
2	SG 42	same
3	SG 43	same
4	date/time	see chart at left
5	SG 44	same as 1.
6	SG 45	same
7	SG 46	same
8	thrust aft ctr	
9	thrust aft port	
10	thrust aft stbd	

Chart
Paper Speed: 12 in/sec./________in/sec.
mm/sec.
div/sec.

Time at start of data point________ End_______

Avg thrust aft ctr	_____	x 100,000 =	_____	lbs
Max thrust aft ctr	_____	x 100,000 =	_____	lbs
Min thrust aft ctr	_____	x 100,000 =	_____	lbs
Avg thrust aft port	_____	x 100,000 =	_____	lbs
Max thrust aft port	_____	x 100,000 =	_____	lbs
Min thrust aft port	_____	x 100,000 =	_____	lbs
Avg thrust aft stbd	_____	x 100,000 =	_____	lbs
Max thrust aft stbd	_____	x 100,000 =	_____	lbs
Min thrust aft stbd	_____	x 100,000 =	_____	lbs

DATA SHEET 12 (Continued)

TIME	SG 41	SG 42	SG 43	SG 44	SG 45	SG 46

NOTES:

1. Use a straightedge to strike the average values for channels 8, 9 and 10.
2. Measure the signals to within 0.05 inches.
3. Transcribe the times of occurrences of strain gage peaks from Data Sheet #9 onto this worksheet. Then measure and record the signals occurring at the same time on this data.

COMMENTS:

DATA SHEET 13

FIRST-LEVEL WORKSHEET FOR OSCILLOGRAPH #2, PASS #1

Today's Date__________ Data Point NR_________

Your Name______________________________________

Channel Number	Channel Contents	Sketches
1	SG 51	
2	SG 52	same
3	SG 53	same
4	SG 54	same
5	date/time	
6	SG 55	same as 1.
7	SG 56	same
8	ctr astern Hy. Pr.	
9	not used	
10	not used	

Chart Paper Speed: 12 in/sec./________in/sec.
mm/sec.
div/sec.

Time at start of data point________ End________

Avg. Hydraulic press. _____ x 500 = _____ psid

Max. Hydraulic press _____ x 500 = _____ psid

Min. Hydraulic press. _____ x 500 = _____ psid

DATA SHEET 13 (Continued)

TIME	SG 51	SG 52	SG 53	SG 54	SG 55	SG 56

NOTES:

1. Use a straightedge to strike an average for channel 8.
2. Measure signals to within 0.05 inches.
3. Select the ten largest impact signals from the strain gage oscillograph traces. Record the time of occurrence of each of the selected impacts, and record the magnitude of all of the strain gage signals for each of the selected impacts.

COMMENTS:

DATA SHEET 14

FIRST-LEVEL WORKSHEET FOR OSCILLOGRAPH #2, PASS #2

Today's Date__________ Data Point NR_________

Your Name______________________________________

Channel Number	Channel Contents	Sketches
1	SG 61	
2	SG 62	same
3	SG 63	same
4	SG 64	same
5	SG 65	same
6	date/time	
7	SG 66	same as 1.
8	thrust ctr fwd #2	
9	thrust stbd fwd #1	
10	shaft torque, port	

Chart
Paper Speed: 12 in/sec./________in/sec.
mm/sec.
div/sec.

Time at start of data point________ End_________

Avg thrust ctr fwd #2 _____ x 100,000 = _____ lbs

Max thrust ctr fwd #2 _____ x 100,000 = _____ lbs

Min thrust ctr fwd #2 _____ x 100,000 = _____ lbs

Avg thrust stbd fwd #1 _____ x 100,000 = _____ lbs

Max thrust stbd fwd #1 _____ x 100,000 = _____ lbs

Min thrust stbd fwd #1 _____ x 100,000 = _____ lbs

Avg shaft torque, port _____ x 1,500,000 = _____ft. lbs.

Max shaft torque, port _____ x 1,500,000 = _____ft. lbs.

Min shaft torque, port _____ x 1,500,000 = _____ft. lbs.

DATA SHEET 14 (Continued)

TIME	SG 61	SG 62	SG 63	SG 64	SG 65	SG 66

NOTES:

1. Use a straightedge to strike the average values.
2. Measure signals to within 0.05 inches.
3. Transcribe the times of occurrence of strain gage peak signals from Data Sheet #13 onto this worksheet. Then measure and record the signals occurring at the same time on this data.

COMMENTS:

DATA SHEET 15

FIRST-LEVEL WORKSHEET FOR OSCILLOGRAPH #2, PASS #3

Today's Date__________ Data Point NR__________

Your Name______________________________________

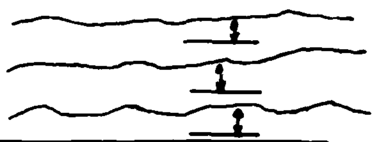
Channel Number	Channel Contents	Sketches
1	SG 71	
2	SG 72	same
3	SG 73	same
4	SG 74	same
5	SG 75	same
6	SG 76	same
7	date/time	
8	Gen (1A) megawatts	
9	Gen (1B) megowatts	
10	port astern hy. pr.	

Chart Paper Speed: 12 in/sec./________in/sec.
mm/sec.
div/sec.

Time at start of data point__________ End________

Gen (1A) megawatts _____ x 3.6 = _____Mwatts

Gen (1B) megawatts _____ x 3.6 = _____Mwatts

Avg hydraulic pressure, port _____ x 500 = _____psid

Max hydraulic pressure, port _____ x 500 = _____psid

Min hydraulic pressure, port _____ x 500 = _____psid

DATA SHEET 15 (Continued)

TIME	SG 71	SG 72	SG 73	SG 74	SG 75	SG 76

Signal	Pk at Undershoot	Pk at Overshoot	Cycles of Ringing	Other
Hydraulic press., port				

NOTES:

1. Use a straightedge to strike the average values.
2. Measure signals to within 0.05 inches.
3. Transcribe the times of occurrence of strain gage signal peaks from Data Sheet #13 onto this worksheet. Then measure and record the signals occurring at the same time on this data.

COMMENTS:

DATA SHEET 16

FIRST-LEVEL WORKSHEET FOR OSCILLOGRAPH #2, PASS #4

Today's Date__________ Data Point NR_________

Your Name______________________________________

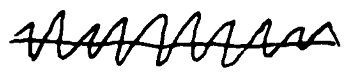
Channel Number	Channel Contents	Sketches
1	SG 81	
2	SG 82	same
3	SG 83	same
4	SG 84	same
5	SG 85	same
6	SG 86	same
7	stbd astern hy. pr.	
8	date/time	
9	Gen (2A) watts	
10	Gen (2B) watts	
11	thrust fwd stbd #2	

Chart
Paper Speed: 12 in/sec./________in/sec.
mm/sec.
div/sec.

Time at start of data point________ End_________

Avg hydraulic pressure, stbd _____ x 500 = _____psid

Max hydraulic pressure, stbd _____ x 500 = _____psid

Min hydraulic pressure, stbd _____ x 500 = _____psid

Gen (2A) megawatts _____ x 3.6 = _____Mwatts

Gen (2B) megawatts _____ x 3.6 = _____Mwatts

DATA SHEET 16 (Continued)

TIME	SG 81	SG 82	SG 83	SG 84	SG 85	SG 86

Signal	Pk at Undershoot	Pk at Overshoot	Cycles of Ringing	Other
Hydraulic press., stbd				

NOTES:

1. Use a straightedge to strike an average value for 7, 9, 10 and 11.
2. Measure signals to within 0.05 inches.
3. Transcribe the times of occurence of strain gage signal peaks from Data Sheet #13 onto this worksheet. Then measure and record the signals occurring at the same time on this data.

COMMENTS:

V. BRIDGE LOGSHEET

V. BRIDGE LOGSHEET

DATA SHEET 17

CGC POLAR STAR ARCTIC TESTS

BRIDGE LOGSHEET

Date________________ Run NR____________

Location__________________Lat.________ Long.__________

Heading (start)__________°T Heading (end)_____________°T

Wind speed______ kts Dir.____°T Temp.____°F Cloud cvr.____(1/10's)

Ice Thick.____ins. Snow Amt.____% Thick____ins.

Test: C-1a - Crash Rev. ______________________________

A-1a - Cont. Iceb.______________________________

A-1b - Static Res.______________________________

A-2a - Ram Unif.______________________________

A-2b - Ram Ridge______________________________

A-1c - Heeling______________________________

A-3 - Maneuvering______________________________

C-2 - Ice Milling______________________________

B-2 - Rudder Ice______________________________

Planned Power:	(Port)								
	(Ctr)								
	(Stbd)								
Actual Power:	(Port)								
	(Ctr)								
	(Stbd)								

Speed Flags: Port/Stbd Spacing 200/____

Acceleration Flags: Port/Stbd Spacing____/____/____/____

Rudder: Amidships/Steer course/Twist______________________

____

DATA SHEET 17 (Continued)

Heeling System: ON/OFF Start:_____ Stop:_____

Photo helo airborne? Yes/No Port/Stbd Fwd/Aft

For ramming tests: Time from impact to stop:________secs.

Ice Pressure: None Light Medium Heavy Unknown

COMMENTS:

VI. SECOND LEVEL WORKSHEETS

DATA SHEET 18

SECOND-LEVEL WORKSHEET FOR TEST A-1a,
CONTINUOUS ICEBREAKING RESISTANCE

Today's Date______________ Data Point NR________________

Your Name__________________________ Lat.______ Long._______

Ship's Heading_______________ °T Precipitation______________

Wind speed_____kts Dir._____°T Air Temp._____ Cloud cvr._____(1/10's)

Ice Thick.______ ±_____cm. Snow cover_____%, _____ ± _____cm.

Ice Density_______gm/cm³ Coefficient of friction___________

Ice Temperature (surface) _____°C Flexural Strength_________Kg/cm²

Ship's Speed:

From doppler _____FPS From flags _____FPS From Ranger _____FPS

	PORT	CTR	STBD
RPM			
Pitch			
Torque #1 (ft-lbs)			
Torque #2 (ft-lbs)			
Thrust #1 (lbs)			
Thrust #2 (lbs)			
Volts			
Amps			

	From Thrust	From Torque/ RPM/Pitch	From Volts/AMPS/ RPM/Pitch
Resistance (lbs)			

Attachments

Histograms of: RPM (3 each) Torque (4 each)
Pitch (3 each) Thrust (6 each)

NOTE: Equations on reverse side and following pages.

DATA SHEET 18 (Continued)

Equations:

(1) Resistance from thrust sensors:

$$\text{thrust (per shaft)} = 8 \; \frac{\text{Thrust \#1 + Thrust \#2}}{2}$$

total thrust = thrust (port) + thrust (ctr) + thrust (stbd)

resistance = (TCF) (total thrust),

where TCF is obtained from the graph in Figure 37.

(2) Resistance estimate from torque, RPM and pitch measurement:

(a) Calculate for each propeller $K_Q = \dfrac{Q}{\rho n^2 D^5}$

where K_Q = torque coefficient

Q = torque in ft-lbs.

n = rev/sec = RPM/60

D = propeller diameter = 16 feet

ρ = density of SW = 1.9947 lb-sec^2/ft^4 at 32°F

= 1.9940 " at 40°F

= 1.9924 " at 50°F

= 1.9903 " at 60°F

(b) Calculate the pitch ratio $\frac{p}{D}$

where p = pitch expressed in feet

D = diameter = 16 feet

(c) Enter the propeller curves with K_Q and p/D and record J and K_T

where $J = \dfrac{V_a}{nD}$ = advance ratio

$K_T = \dfrac{T}{\rho n^2 D^4}$ = thrust coefficient

$V_a = V(1 - \omega_Q)$ = speed of advance

V = ship speed in ft/sec.

ω_Q = wake fraction based on torque identity

DATA SHEET 18 (Continued)

(d) Calculate thrust

$$T = K_T \rho n^2 D^4$$

This assumes that $\omega_T = \omega_Q$; that is, the wake fraction ω_T based on thrust identity is the same as the wake fraction ω_Q based on the torque identity. These are usually somewhat different; but lacking experimental data, this assumption can be made without introducing significant error.

(e) Calculate:

Total thrust = thrust (port) + thrust (ctr) + thrust (stbd)

resistance = (TCF) (total thrust)

where TCF is obtained from the graph in Figure 37.

(3) Resistance estimated from Volts/Amps/RPM/Pitch measurements:

(a) Calculate for each shaft

$$SHP = \frac{(V)(I)}{745.7} \text{ X motor efficiency}$$

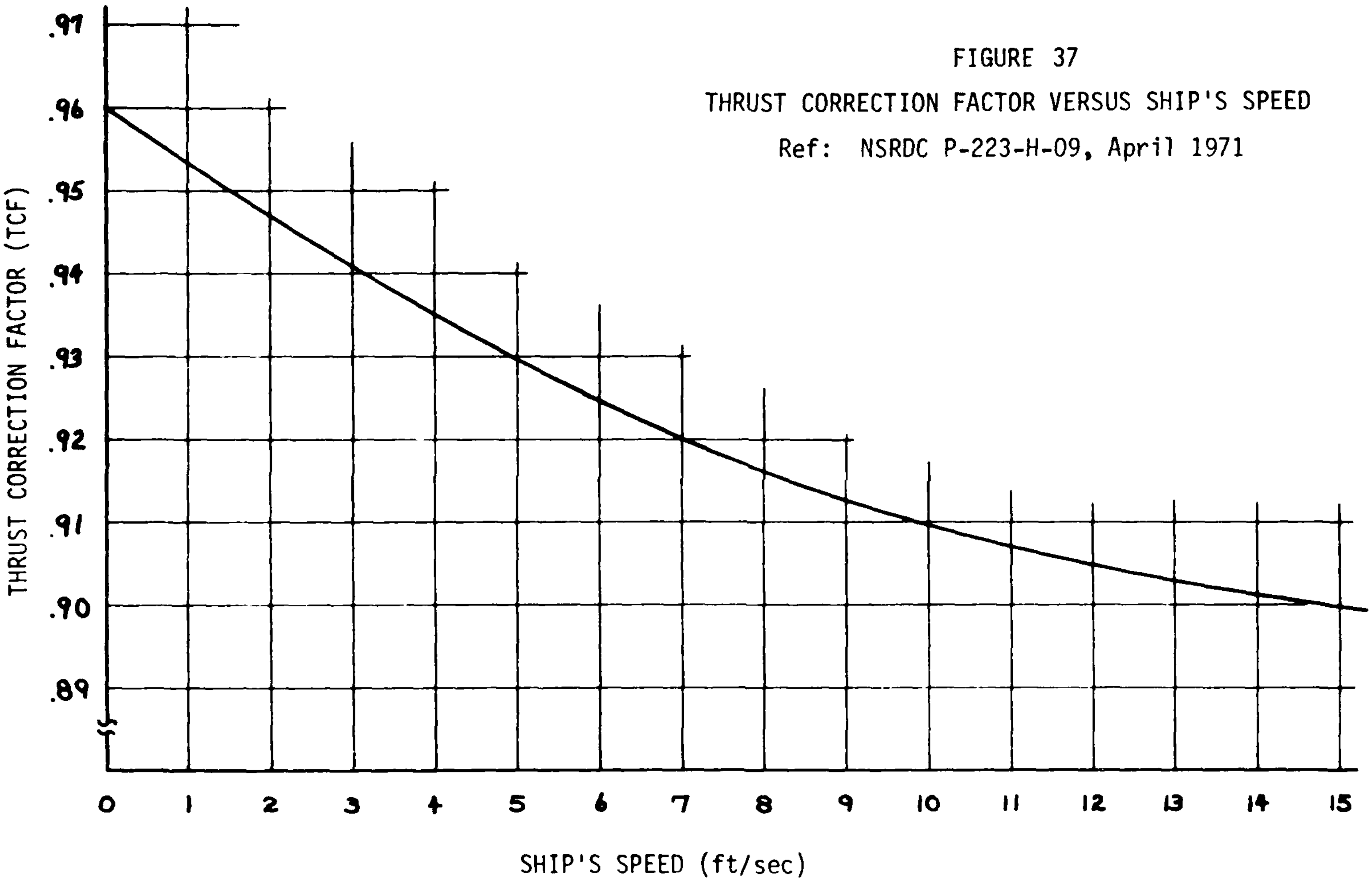
$$Q = \frac{33{,}000 \text{ (SHP)}}{2\pi \text{ (RPM)}}$$

(b) Calculate (for each propeller) K_Q and p/D and enter propeller curves as in (2) above. Calculate thrust and resistance.

FIGURE 37

THRUST CORRECTION FACTOR VERSUS SHIP'S SPEED

Ref: NSRDC P-223-H-09, April 1971



DATA SHEET 19

SECOND-LEVEL WORKSHEET FOR TEST A-1b, STATIC (STARTING) ICEBREAKING RESISTANCE

Today's Date______________ Data Point NR________________

Your Name__________________________ Lat._______ Long._______

Ship's Heading_______________ °T Precipitation___________

Wind speed_____kts Dir._____°T Air Temp._____°F Cloud cvr._____(1/10's)

Ice Thick._____ ± _____cm. Snow cover_____%, _____ ± _____cm.

Ice Density_______gm/cm³ Coefficient of friction__________

Ice Temperature (surface) _____°C Flexural Strength________Kg/cm²

	PORT	CTR	STBD
RPM			
Pitch			
Torque #1 (ft-lbs)			
Torque #2 (ft-lbs)			
Thrust #1 (lbs)			
Thrust #2 (lbs)			
Volts			
Amps			

	From Thrust	From Torque/ RPM/Pitch	From Volts/AMPS/ RPM/Pitch
Resistance (lbs)			

<u>Equations:</u> (Refer to Data Sheet 18)

DATA SHEET 20

SECOND-LEVEL WORKSHEET FOR TEST A-1c, HEELING SYSTEM

Today's Date_______________ Data Point NR_________________

Your Name____________________________ Lat._______ Long._______

Ship's Heading________________°T Precipitation____________

Wind Speed_____kts Dir._____°T Air Temp._____°F Cloud cvr._____(1/10's)

Ice Thick._____ ± _____cm. Snow cover_____%, _____ ± _____cm.

Ice Density_______gm/cm³ Coefficient of friction___________

Ice Temperature (surface) _____°C Flexural Strength_________Kg/cm²

Ship's Speed:

From doppler _____FPS From flags _____FPS From Ranger _____FPS

Max. roll angles: Stbd_____ Port_____ NR of cycles_____

Ship's draft Fwd_____ Aft_____

	PORT	CTR	STBD
RPM			
Pitch			
Torque #1 (ft-lbs)			
Torque #2 (ft-lbs)			
Thrust #1 (lbs)			
Thrust #2 (lbs)			
Volts			
Amps			

	From Thrust	From Torque/ RPM/Pitch	From Volts/AMPS/ RPM/Pitch
Resistance (lbs)			

<u>Equations</u>: (Refer to Data Sheet 18)

DATA SHEET 21

SECOND-LEVEL WORKSHEET FOR TEST A-1d, CLOGGED CHANNEL RESISTANCE

Today's Date_______________ Data Point NR_________________

Your Name___________________________ Lat._______ Long._______

Ship's Heading________________°T Precipitation_____________

Wind speed_____kts Dir._____°T Air Temp._____°F Cloud cvr._____(1/10's)

Ice Thick._____ ± _____cm. Snow cover _____%, _____ ± _____cm.

Ice Density_______gm/cm^3 Coefficient of friction___________

Ice Temperature (surface) _____°C Flexural Strength________Kg/cm^2

Channel Width _____ft. Average piece size ________sq ft.

Coverage ________(1/10's) Est. ice Pressure: Neg. Neut. Pos.

Ship's Speed:

From doppler____FPS From flags____FPS From Ranger ____FPS

Ship's draft Fwd____ Aft____

	PORT	CTR	STBD
RPM			
Pitch			
Torque #1 (ft-lbs)			
Torque #2 (ft-lbs)			
Thrust #1 (lbs)			
Thrust #2 (lbs)			
Volts			
Amps			

	From Thrust	From Torque/ RPM/Pitch	From Volts/AMPS/ RPM/Pitch
Resistance (lbs)			

<u>Equations</u>: (Refer to Data Sheet 18)

DATA SHEET 22

SECOND-LEVEL WORKSHEET FOR TEST A-2a,
RAMMING AND EXTRACTION IN UNIFORM ICE

Today's Date______________ Data Point NR_________________

Your Name__________________________ Lat._______ Long._______

Ship's Heading________________ °T Precipitation____________

Wind speed_____kts Dir._____°T Air Temp.____°F Cloud cvr._____(1/10's)

Ice Thick._____ ± _____cm. Snow cover_____%, _____ ± _____cm.

Ice density________gm/cm^3 Coefficient of friction___________

Ice Temperature (surface)_____°C Flexural Strength________Kg/cm^2

Ramming Data: Impact speed (doppler)_____FPS

Impact speed (flag) _____FPS

Impact speed (Ranger) _____FPS

Acceleration Distance ________ft. Penetration Distance________ft.

Trim at end of ram___________________

Time duration, contact to stop:________sec.

Peak surge deceleration:_____G's Peak pitch acceleration:_____G's

Ice Pressure: None Light Medium Heavy

Ship's draft Fwd___________ Aft___________ (in open water)

EXTRACTION DATA	PORT	CTR	STBD
RPM			
Pitch			
Torque #1 (ft-lbs)			
Torque #2 (ft-lbs)			
Thrust #1 (lbs)			
Thrust #2 (lbs)			
Volts			
Amps			

DATA SHEET 22 (Continued)

	From Thrust	From Torque/ RPM/Pitch	From Volts/AMPS/ RPM/Pitch
Extraction Resistance (lbs)			

Equations: (Refer to Data Sheet 18)

DATA SHEET 23

SECOND-LEVEL WORKSHEET FOR TEST A-2b,
RAMMING AND EXTRACTION, PRESSURE RIDGES

Today's Date______________ Data Point NR_________________

Your Name____________________________ Lat._______ Long._______

Ship's Heading_______________ Precipitation____________

Wind speed_____kts Dir._____°T Air Temp._____°F Cloud cvr._____(1/10's)

Ice Density_______gm/cm^3 Coefficient of friction___________

Ice Temperature (surface) _____°C Flexural Strength_________Kg/cm^2

Ramming Data: Impact speed (doppler _____FPS

Impact speed (flag) ______FPS

Impact speed (Ranger) _____FPS

Acceleration Distance _______ft. Penetration Distance_______ft.

Time duration, contact to stop: _______sec.

Peak surge deceleration: _____G's Peak pitch acceleration:_____G's

Ice/ridge profile: Attached

Max. height _____ Max. width _____ Ice type _____

Ice Pressure: None Light Medium Heavy

Ship's draft Fwd_____ Aft_____

EXTRACTION DATA	PORT	CTR	STBD
RPM			
Pitch			
Torque #1 (ft-lbs)			
Torque #2 (ft-lbs)			
Thrust #1 (lbs)			
Thrust #2 (lbs)			
Volts			
Amps			

DATA SHEET 23 (Continued)

	From Thrust	From Torque/ RPM/Pitch	From Volts/AMPS/ RPM/Pitch
Extraction Resistance (lbs)			

Equations: (Refer to Data Sheet 18)

DATA SHEET 24

SECOND-LEVEL WORKSHEET FOR TEST A-3, MANEUVERING

Today's Date_______________ Data Point NR________________

Your Name___________________________ Lat._______ Long._______

Ship's Heading (start)______°T Precipitation_______ Visibility____

Wind Speed_____kts Dir._____°T Air Temp._____°F Cloud cvr._____(1/10's)

Ice Thick._____ ± _____cm. Snow cover_____%, _____ ± _____cm.

Ice Density_______gm/cm^3 Coefficient of friction___________

Ice Temperature (surface) _____°C Flexural Strength__________Kg/cm^2

Ship's Speed: From doppler _____kts. From fixes _____kts.

Nav. System: Ranger_______ Masts______ Transit______

Power: Diesel or turbines

Distribution: Port ______ Ctr._______ Stbd________

Rudder angle (max.) _____°, R or L, heading at end _____°T

Track plot: Attached

Advance ________ yds.

Transfer ________yds.

Tactical diameter ________yds.

Turn radius ________yds.

Ship's draft Fwd_____ Aft_____.

DATA SHEET 25

SECOND-LEVEL WORKSHEET FOR TEST A-4,
HULL FRICTION TEST

Today's Date______________ Data Point NR______________

Your Name__________________________ Lat.______ Long.______

Ship's Heading______________ Precipitation____________

Wind Speed_____kts Dir._____°T Air Temp._____°F Cloud cvr._____(1/10's)

Ice Temperature (surface) _____°C

Ice Density _____gm/cm^3

Block orientation ________________________________

N = measured normal force

F = measured friction force

V = Speed

f = coefficient of friction = $\frac{F}{N}$

Block No.	Size L x B x H (cm)	V (fps)	N (lbs)	F (lbs)	f
1					
2					
3					
4					
5					

DATA SHEET 26

SECOND-LEVEL WORKSHEET FOR TEST B-1,
HULL IMPACT FORCES

Today's Date_______________ Data Point NR_______________

Your Name____

Ship's Heading _____°T

Wind speed_____kts. Dir._____°T Air Temp._____°F

Ice thick._____ ± _____cm. Snow cover_____%, _____ ± _____cm.

Ice Density_______gm/cm^3 Coefficient of friction___________

Ice Temperature (surface) _____°C Flexural Strength_______Kg/cm^2

Ship's draft: Fwd _____ft._____in. Aft _____ft._____in.

Ship's Speed:

From doppler _____FPS From flags _____FPS From Ranger _____FPS

Histogram of load forces: Attached

Histogram of load locations: Attached

DATA SHEET 27

SECOND-LEVEL WORKSHEET FOR TEST B-2,
RUDDER ICE IMPACT

Today's Date______________ Data Point NR_______________

Your Name____

Ship's Heading _______°T

Wind speed_____kts. Dir._____°T Air Temp._____°F

Ice Thick._____ ± _____ cm. Snow cover _____%, _____ ± _____cm.

Ice Density_______gm/cm^3 Coefficient of friction__________

Ice Temperature (surface) _____°C Flexural Strength_______Kg/cm^2

Ship's draft: Fwd _____ft._____in. Aft _____ft._____in.

Ship's Speed:

From doppler_____FPS From flags _____FPS From Ranger _____FPS

Histogram of rudderstock torque: Attached

Ship Activity: Continuous Icebreaking ☐

Ramming ☐

Backing ☐

Turning ☐

DATA SHEET 28

SECOND-LEVEL WORKSHEET FOR TEST C-1,
PROPULSION SYSTEM CONTROLS

Today's Date________________ Data Point NR________________

Your Name____

Ship's Heading ________°T

Wind speed______kts. Dir.______°T Air Temp.______°F

Ice Thick. _____ ± _____cm. Snow cover _____%, _____ ± _____cm.

Ice Density________gm/cm^3 Coefficient of friction___________

Ice Temperature (surface) _____°C Flexural Strength________Kg/cm^2

Ship's draft: Fwd ______ft._____in. Aft ______ft._____in.

Ship's Speed:

From doppler _____FPS From flags______FPS From Ranger _____FPS

Ship's Activity: Crash Reversal

Continuous Icebreaking

Ramming

Parameter	% Overshoot	% Undershoot	Cycles of Ringing
Ctr G.T. N_1			
Ctr G.T. N_2			
Ctr G.T. Throttle			
Ctr G.T. O/L gate			
Port G.T. N_1			
Port G.T. N_2			
Port G.T. Throttle			
Port G.T. O/L gate			
Stbd G.T. O/L gate			

DATA SHEET 28 (Continued)

Parameter	% Overshoot	% Undershoot	Cycles of Ringing
Engine 3A RPM			
Engine 3A fuel			
Engine 3B RPM			
Engine 3B fuel			
Engine 2A RPM			
Engine 2B RPM			
Ctr Brg Cont.			
Port Brg Cont.			
Stbd Brg Cont.			
Ctr Pitch Cmd			
Port Pitch Cmd			
Stbd Pitch Cmd			
Ctr Prop Angle			
Port Prop Angle			
Stbd Prop Angle			
Ctr Hyd Press.			
Port Hyd Press.			
Stbd Hyd Press.			
Gen 3A volts			
Gen 3A amps			
Gen 3A field volts			
Gen 3A field amps			
Gen 3B volts			
Gen 3B amps			
Gen 3B field volts			
Gen 3B field amps			
Gen 2A volts			
Gen 2A amps			
Gen 2A field volts			
Gen 2A field amps			

DATA SHEET 28 (Continued)

Parameter	% Overshoot	% Undershoot	Cycles of Ringing
Gen 2B volts			
Gen 2B amps			
Gen 2B field volts			
Gen 2B field amps			
Ctr Motor volts			
Ctr Motor amps			
Ctr Mtr field volts			
Ctr Mtr field amps			
Stbd Motor volts			
Stbd Motor amps			
Stbd Mtr field volts			
Stbd Mtr field amps			

DATA SHEET 29

SECOND-LEVEL WORKSHEET FOR TEST C-2,
PROPELLER ICE IMPACT

Today's Date________________ Data Point NR_________________

Your Name____

Ship's Heading ________°T

Wind speed______kts. Dir ______°T Air Temp.______°F

Ice Thick. _____ ± _____cm. Snow cover _____%, _____ ± _____cm.

Ice Density________gm/cm^3 Coefficient of friction____________

Ice Temperature (surface) ______°C Flexural Strength_________Kg/cm^2

Ship's draft: Fwd ______ft._____in. Aft ______ft._____in.

Ship's Speed:

From doppler _____FPS From flag _____FPS From Ranger _____FPS

Attachments

Histograms of: Shaft RPM
Propeller pitch angle command
Propeller pitch angle feedback

	Block 1	Block 2	Block 3	Block 4	Block 5
Depth of cut					
Width of cut					
Blade advance					

Ship's Activity: Continuous Icebreaking ☐
Ramming ☐
Backing ☐
Turning ☐

DATA SHEET 30

SECOND-LEVEL WORKSHEET FOR TEST C-3,
SHAFT TORSIONAL VIBRATION

Today's Date________________ Data Point NR__________________

Your Name____

Ship's Heading ________°T

Wind speed______kts. Dir. _____°T Air Temp.______°F

Ice Thick. _____ ± _____cm. Snow cover _____%, _____ ± _____cm.

Ice Density________gm/cm^3 Coefficient of friction___________

Ice Temperature (surface) ______°C Flexural Strength_______Kg/cm^2

Ship's draft: Fwd ______ft._____in. Aft ______ft._____in.

Ship's speed:

From doppler _____FPS From flag _____FPS From Ranger _____FPS

Ship's Activity: Continuous Icebreaking ☐

Ramming ☐

Backing ☐

Turning ☐

Open water ☐

Attachments

Histograms of: Shaft Torque
Propeller RPM
Propeller Pitch
Frequency Spectrum of Shaft Torque

DATA SHEET 31

SECOND-LEVEL WORKSHEET FOR TEST C-4,
ENGINE COOLING AND RECIRCULATION

Today's Date_______________ Data Point NR_________________

Your Name____

Ship's Heading ___________°T

Wind speed _____kts. Dir.______°T Air Temp.______°F

Ice Cover ______% Average thickness ______cm.

Ship's draft: Fwd ______ft._____in. Aft ______ft._____in.

Ship's Speed:

From doppler _____FPS From flag _____FPS From Ranger _____FPS

Ship's Activity: Continuous Icebreaking ☐

Ramming ☐

Beset ☐

Open water ☐

Load	On Line	Supply Temp	Return Temp	Supply Flow	Flow Rel. Point	
Gen 1A						
Gen 1B						
Gen 2A						
Gen 2B						
Gen 3A						
Gen 3B						
SS Gen 1						
SS Gen 2						
SS Gen 3						
Ctr Mtr						
Port Mtr						
Stbd Mtr						

DATA SHEET 32

SECOND-LEVEL WORKSHEET FOR TEST C-5,
MEASURED MILE SENSOR CALIBRATION

Today's date_______________ Data Point NR__________________

Your Name____

Measured Mile Courses: _______°T/_______°T

Power Levels: _______ Port/ _______Ctr/ _______Stbd

Wind Speed _____ kts. from _____°T, Wave height _____ft. from_____°T

Predicted tidal current: _____its. from _____°T

Ship's draft: Fwd _____ft_____in. Aft _____ft._____in.

Time between ranges: _____min._____sec., Speed _____kts.

	PORT	CTR	STBD
RPM			
Pitch			
Thrust #1 (lbs)			
Thrust #2 (lbs)			
Torque #1 (ft-lbs)			
Torque #2 (ft-lbs)			
Volts			
Amps			

Predicted resistance: _________lbs ± _________lbs.

Calculated resistance (thrust): _________lbs ± _________lbs.

Calculated resistance (torque): _________lbs ± _________lbs.

Calculated resistance (watts): _________lbs ± _________lbs.

VII. ICE DATA COLLECTION PROCEDURES

A. General

The procedures described in the following have been used on previous ice/icebreaker tests; they work but can always stand improvement. Data sheet 33 gives the overall ship track ice thickness measurement scheme. The majority of ice property sampling sites are determined by reference to the positions located using data sheet 33. Data sheet 34 shows the layout for the field notebook. All ice properties measured are recorded in the field notebook. Two notebooks are maintained one for use on the ice and one which is kept on the ship. Each notebook contains the same information by the end of each day so that no more than one day of data will be lost if a notebook is lost. Some of the procedures include numerous steps between a measurement and result, thus individual data sheets have been developed to help obtain the results. The procedures and sample data sheets follow.

B. Ice Thickness

1. Equipment - Auger; extensions, tape, speed handle, spud, 3/16" line (50') and antifreeze (1 gallon).

2. Extra - Electric drill with adapter and generator

3. Sampling Scheme - Make measurements at distances shown on data sheet 33.

4. Procedure - Attach handle (or drill) to auger - place auger tip against the side of boot on surface of ice - turn clockwise - lift out and shake about every 10 cm depth. If air temp is below freezing pour about 1/3 of a cup of antifreeze into hole when down about 10 to 15 cm. When auger is 1/2 in remove and add 1/2 meter extension - when in another 1/2 meter remove 1/2 meter extension and add 1 meter extension - always remove auger from hole when adding or removing extensions and check detent pin before continuing. If drill string becomes stuck in the ice try the antifreeze first then try to secure as much of the drill as possible and start a hole next to it with the spud. Try not to hit drill with spud. Use 3/16" line to secure drill string and spud. When through the ice, work the drill string up and down a few times to remove slush from hole. Take tape with toggle and lower into hole - you will have an estimate of how far to lower from the number of extensions required to make the hole. Let the toggle catch the bottom of the ice and pull up (gently!) on the tape (not the cable) read the thickness at this time. Record the results in field notebook (data sheet 34). Stow equipment after checking detent pins.

C. Ice Temperature

1. Equipment - Corer, extensions, handle, starter, spud, back saw, mitre box, metric rule, thermometers, small drill with bit, pins, 3/16" line (50').

2. Procedure - Electric drills with adapters and generator. Remove protective cover from corer - attach handle (or drill) - place starter on ice and place corer inside (can also place between two feet) turn clockwise - try to turn at same speed without jerky motions (to prevent core from breaking) when down about one meter remove from hole - remove handle with head and gently dump out the ice core (make sure you know which end is the top) - place in mitre box, drill 1/4" holes to center of core from side starting 5 cm down from the top and every 10 cm thereafter until you run out of ice core - place thermometers in holes in order - try to complete this part within 10 minutes total elapsed time as the ice will be cooling off or warming up to the air temperature. Continue for each meter of ice core recovered. When temperature has been recorded (in field notebook) cut the ice core into 10 cm long sections (between the holes) and place each in a freezer container - record in the field notebook then number on each container by depth of core section from ice surface - stow containers for return to the lab (will use these ice samples for density and salinity measurements). If the air temperature is above freezing the density measurement will have to be made before putting core section into container. Check all equipment and stow away. Try to protect cutting bits of the corer from impact.

D. Salinity

1. Equipment - Salinometer, cell and wash water, 2 extra containers (one for wash water and one for waste water).

2. Procedure - Record sample container number on data sheet 35 and refer to field notebook for distance from ice surface and temperature at collection time. Wash cell, place thermometer in container with melted sample - draw sample into cell - read salinometer - read thermometer and adjust for temperature - record result on data sheet 35. Wash cell between samples. Try to use distilled water. Draw wash water into cell making sure the electrodes are covered. Repeat three times after each time putting wash water into waste water container. When all samples have been completed, wash cell thoroughly and stow away all equipment. Transfer data to field notebook. Plot salinity profile on data sheet 35 (continued).

E. Snow Density

1. Equipment - Snow tubes with caps, triple beam balance, knife.

2. Procedure - Try to fill tube level with snow by inserting it into the snow (do not pack!) Use knife to remove any excess - place on balance and weigh. Follow sampling scheme and sequence of operations as shown on data sheet 36. Record sample position, container weight and volume on data sheet 36. Perform calculations record and plot results on data sheet 36. Transfer arithmetic mean density to field notebook.

F. Kinetic and Static Friction - Snow/Ice

1. Equipment - Sled, weight, dynamoter, clinometer, tow line and data sheets 38 and 39.

2. Procedure - This is a very crude measurement but useful to obtain a general idea of the friction force. Try not to disturb the surface to be tested. If weight on sled is changed try to use same dynamometer to weigh as used to measure towing force. Before towing measure angle of tow line from horizontal with clinometer. Examine sled surfaces and snow/ice surface before and after test, record observations as comments. Follow order given on Data sheets 38 and 39 and record in appropriate places.

G. Ice Density

1. Equipment - Calipers, metric rule, triple beam balance, ice coring equipment and data form.

2. Note - If air temperature is above freezing make measurement at time of collection. If not, place core sample in numbered container and make measurement on return to lab - do not let sample melt before density measurement is made!

3. Procedure - Measure height and diameter of sample to determine its volume - weight sample and express density in g/cm^3 when samples are core sections - follow sequence of operations on data sheet 37. Record container number and refer to field notebook for depth from surface. Measure height of core section and weigh section. Record and calculate as shown on data sheet 37. Plot ice density profile on reverse of data sheet 37. Record in field notebook.

H. Index of Compressive Strength

1. Equipment - Ramset, #4 and #6 cartridges, studs, measuring rod, small drill and thermometer, and data sheet 40.

2. Procedure - Check ramset carefully! Load ramset - record cartridge size in field notebook - place on ice surface (goggles on - no personnel within 2 meter circle) - fire - remove slowly as as not

to knock snow and ice into hole - use measuring rod to determine penetration - record depth of penetration in field notebook. Follow instructions on data sheet 40 to determine index.

I. Inferred Flexural Strength

1. Equipment - Coring equipment, ice salinity equipment plus data form.

2. Procedure - Record container number and refer to field notebook for ice salinity and temperature at collection time. Use Table 1 on data sheet 41 (continued) to determine relative brine volume V_b - take square root of V_b and enter graph (Figures 1, 2 and 3) of data sheet 41 to determine inferred flexural, compressive, and shear strength respectively. Record.

J. Pressure Ridge Measurement

1. Equipment - Transit/level, tripod, rod, meter tape, sonar transducer, bar of soap (Ivory), corer, extensions, T-handle, pins, data sheet 42 and field notebook.

2. Extra - 3/4" electrical drill with adaptors, 1/4" drill, generator, extension cord.

3. Transport - ATV, sled or back pack

4. Procedure - Sight a line across (perpendicular) to the pressure ridge. If ridge is less than 3 meters above surrounding ice, set up tripod with transit/level on top of ridge carefully!). Level the instrument, record instrument height (IH, vertical distance between center line of telescope and top of ridge directly below tripod - use plumb bob) at left side of 4th column of data sheet 42. Drill core hole at base of ridge approximately 3 meters out from base of ridge.

Measure the vertical distance from the middle of the transducer up the wire to the first or second distance marker on the wire - record. Attach transducer to sonar unit - record distance below water level (col. 1) and range to nearest object (col. 6). Repeat at 1/2 meter depth intervals until over range is indicated - repeat whole process on other side of ridge. Place transducer (after soaping) into water and reckon distance below water level to middle of transducer (be careful not to let transducer get away).

If discrete ice blocks are visible, measure thickness with meter tape and record as many as time permits (NTE 1 hour).

Reduce data as indicated on data sheet 42 and plot profiles as shown on data sheet 42 (continued).

Use tape or transit to measure depth of ship penetration into ridge on an opportunity basis.

DATA SHEET 33
ICE THICKNESS

DATE: TIME:

LOCATION:

WX: (CIRCLE) CAVU OVC SNOWING AIR TEMP.

WIND SPEED________KTS. WIND DIRECTION________ ^{o}T

DISTANCE TO SAMPLING POINT	THICKNESS ICE	SNOW	COMMENTS:
12			
37			
43			
61			
77			
86			
92			
99			
109			
123			
254			
258			
375			
487			
513			
538			
580			
641			
685			
730			
786			
832			
842			
923			
962			

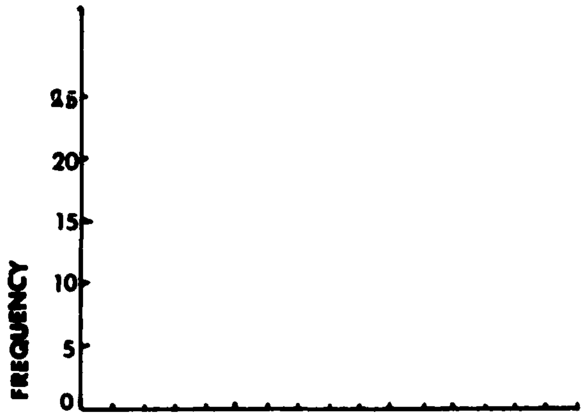
Units of
Distance

(Check One)

Centimeter
Meters
Kilometers

DATA SHEET 33 (Continued)

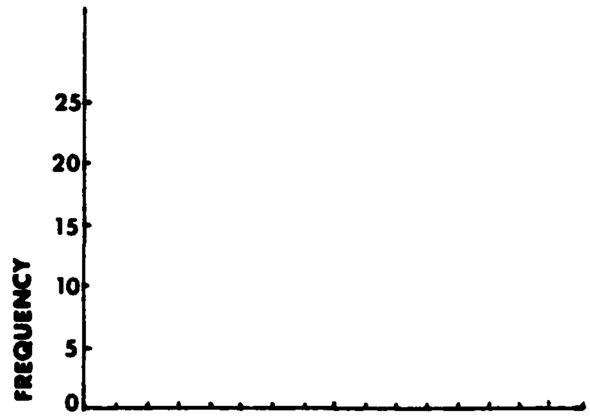
Units of Distance: (Check one) Centimeters Meters Kilometers



ICE THICKNESS

$\bar{X}$ =

s =



SNOW THICKNESS

$\bar{X}$ =

s =

DATA SHEET 34

LAYOUT OF FIELD NOTEBOOK

DEPTH	TEMP.	CONT#	DENSITY	SAL.

DATE ________ TIME ________

LOCATION ________________

THICKNESS: ICE ____ FREEBOARD ____

SNOW ________________

AIR TEMP. ____ WIND ________

CART# ______ PENE: ________

WX: ________________

COMMENTS:

DATA SHEET 35

ICE SALINITY

Today's Date____________________

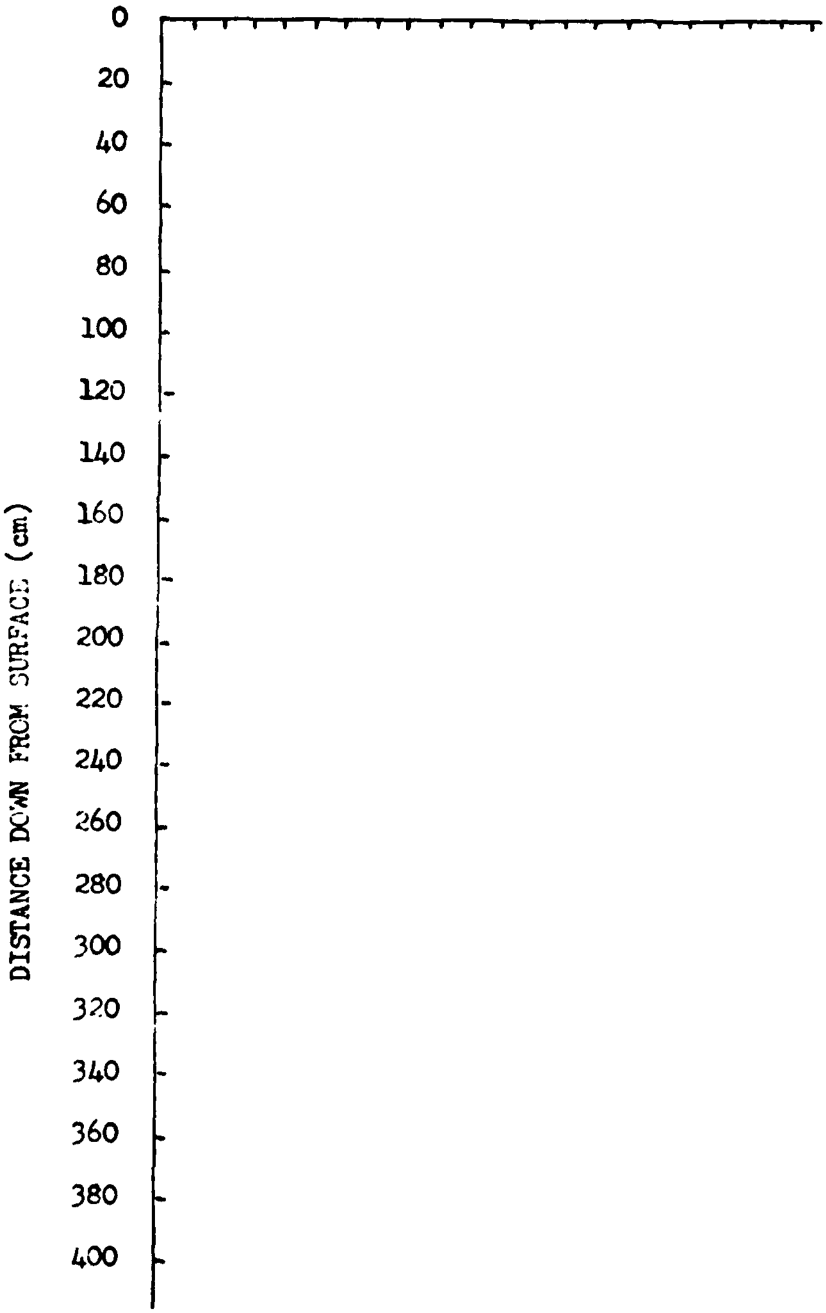
Your Name____

Location____

Distance from Snow or Ice Surface	Sample Container Number	Temperature at Collection Time	Salinity	Temperature at Salinity Measurement Time

DATA SHEET 35 (Continued)

SALINITY (0/00)



DATA SHEET 36

SNOW DENSITY

Today's Date_______________

Your Name__________________________________

Location:______________________

WX: (Circle) CAVU OVC SNOWING

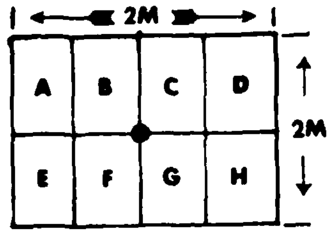
Air Temperature _______°C

Wind speed _______kts. Wind Direction _____________°T

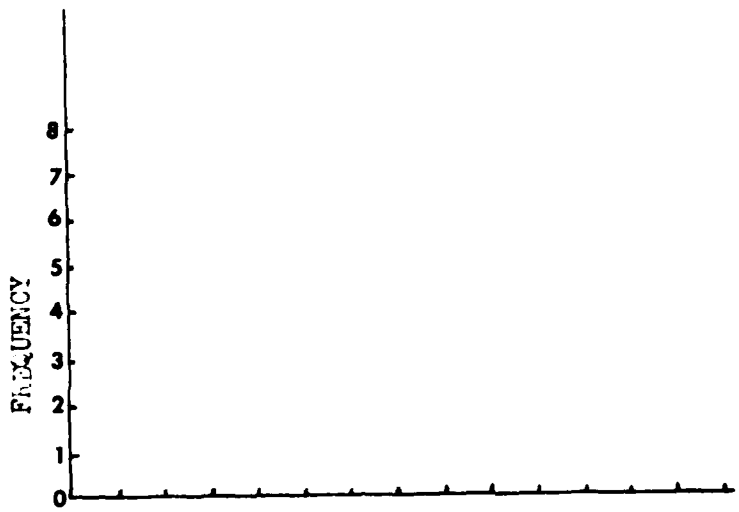
Sample position	Container Weight C(grams)	Container Volume V(cc)	(Snow + Cont.) Total Weight W(grams)	Differ. D = W-C	Density SD = D/V

DATA SHEET 36 (Continued)

SAMPLE POSITION
● THICKNESS MEASUREMENT LOCATION



COMMENTS:



SNOW DENSITY(g/cm^3)

DATA SHEET 37

ICE DENSITY

Today's Date________________

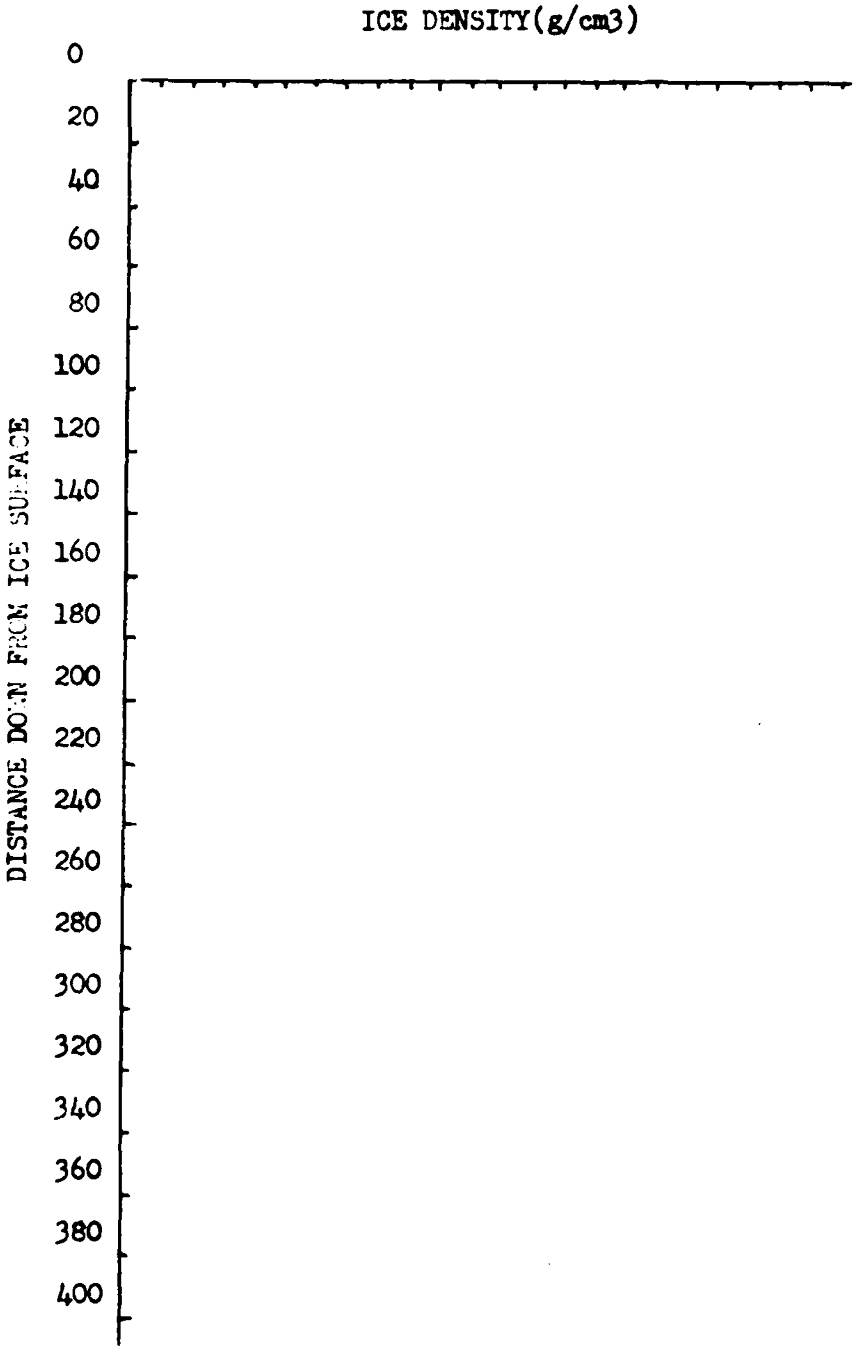
Your Name________________________________

LOCATION ____

Container Number	Depth Surface	Height H(cm)	Volume(cm^3) 40.72 x H	Weight (grams)	Density g/cm^3

DATA SHEET 37 (Continued)

COMMENTS:



DATA SHEET 38

KINETIC FRICTION - SNOW/ICE

Today's Date________________

Your Name____________________________________

Location:_______________________

WX: (Circle) CAVU OVC SNOWING

Air Temperature _______°C Surface Area of runner______________

Wind speed _______kts. Wind Direction ______________°T

Runner Material_______________ Sled Weight__________

Distance	Time	Velocity	Towing Force	Angle	f_k

DATA SHEET 39

STATIC FRICTION - SNOW/ICE

Today's Date_______________

Your Name____________________________________

Location:_______________________

WX: (Circle) CAVU OVC SNOWING

Air Temperature_______°C Surface Area of runner____________________

Wind speed _______kts. Wind Direction ______________°T

Runner Material _______________ Sled Weight ____________

Force to Break Free	Angle	Condition Surface	f_s

DATA SHEET 40

INDEX OF COMPRESSIVE STRENGTH

TODAYS DATE ____________________

YOUR NAME ____________________

LOCATION ____________________

WX.(CIRCLE) CAVU OVC SNOWING

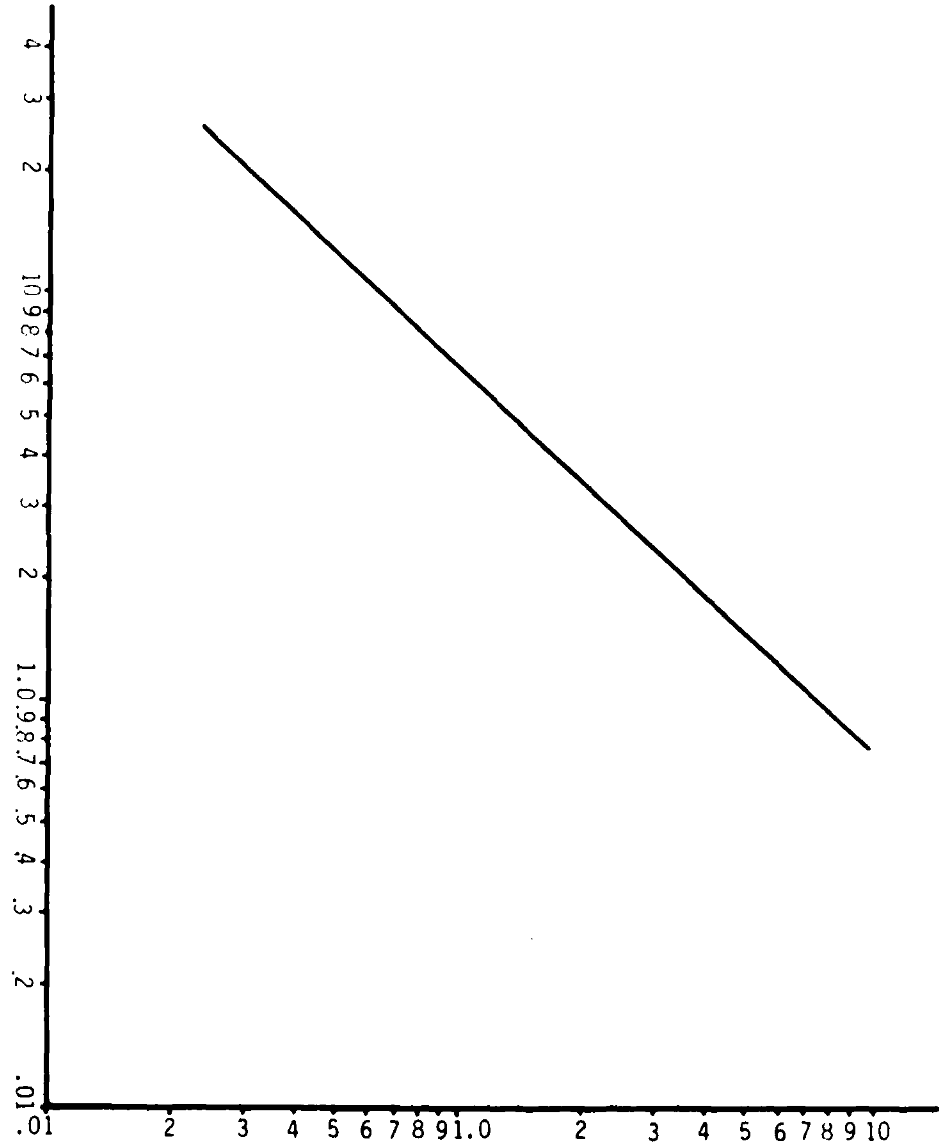
AIR TEMPERATURE ______°C

SAMPLE POSITION	CART. SIZE	PENE. P [mm]	P/9.5	b [table I]	P/9.5+b	INDEX [FIGURE 1]	ICE TEMP °C

DATA SHEET 40 (Continued)

Table 1. Calibration Factor

VALUE OF b	SNOW ICE	CLEAR ICE
4 CARTRIDGE	-5.5	-6.5
6 CARTRIDGE	-8.0	-9.5



ICE STRENGTH $\frac{\sigma d^3}{E} \times 10^2$

Figure 1. Index of ice strength

DATA SHEET 41

INFERRED ICE STRENGTH

TODAYS DATE ____________

YOUR NAME ____________________

LOCATIONS ____________________

WX: (CIRCLE) CAVU OVC SNOWING

AIR TEMPERATURE __________ °C

DISTANCE FROM ICE SURFACE	CONTAINER NUMBER	TEMP. AT COL-LECTION TIME	SALINITY (0/00)	REL. BRINE VOLUME (Vb) Table 1	$\sqrt{V_b}$	STRENGTH K/gcm2 FROM FIGURE		
						FLEXUAL FIGURE 1	COMPRES FIGURE 2	SHEAR FIGURE 3

TEMPERATURE	RELATIVE BRINE VOLUME									
°C	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
-0	-	500.9	250.5	167.1	125.4	100.3	83.66	71.74	62.08	55.85
-1	50.28	45.77	41.87	38.60	35.77	33.29	31.07	29.06	27.23	25.56
-2	24.0	22.8	21.8	20.9	20.1	19.3	18.5	17.9	17.3	16.7
-3	16.2	15.7	15.2	14.8	14.4	14.0	13.6	13.3	13.0	12.7
-4	12.4	12.1	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4
-5	10.2	10.0	9.81	9.64	9.48	9.32	9.16	9.01	8.87	8.73
-6	8.60	8.48	8.36	8.25	8.14	8.03	7.92	7.82	7.72	7.62
-7	7.52	7.43	7.34	7.25	7.16	7.07	6.99	6.91	6.83	6.75
-8	6.67	6.60	6.53	6.46	6.39	6.32	6.26	6.20	6.14	6.08
-9	6.02	5.97	5.92	5.87	5.82	5.77	5.72	5.67	5.62	5.57
-10	5.53	5.49	5.45	5.41	5.37	5.33	5.29	5.26	5.22	5.18
-11	5.15	5.12	5.08	5.05	5.01	4.98	4.95	4.92	4.88	4.85
-12	4.82	4.79	4.76	4.74	4.71	4.68	4.66	4.63	4.61	4.58
-13	4.56	4.54	4.51	4.49	4.46	4.44	4.42	4.40	4.37	4.35
-14	4.33	4.31	4.29	4.27	4.25	4.23	4.21	4.19	4.17	4.15
-15	4.13	4.11	4.09	4.08	4.06	4.04	4.02	4.00	3.99	3.97
-16	3.95	3.93	3.92	3.90	3.89	3.87	3.85	3.84	3.82	3.81
-17	3.79	3.78	3.76	3.75	3.73	3.72	3.71	3.69	3.68	3.66
-18	3.65	3.64	3.62	3.61	3.59	3.58	3.57	3.55	3.54	3.52
-19	3.51	3.50	3.48	3.47	3.45	3.44	3.43	3.42	3.40	3.39
-20	3.38	3.37	3.36	3.34	3.33	3.32	3.31	3.30	3.28	3.27

(after Assur, 1960)

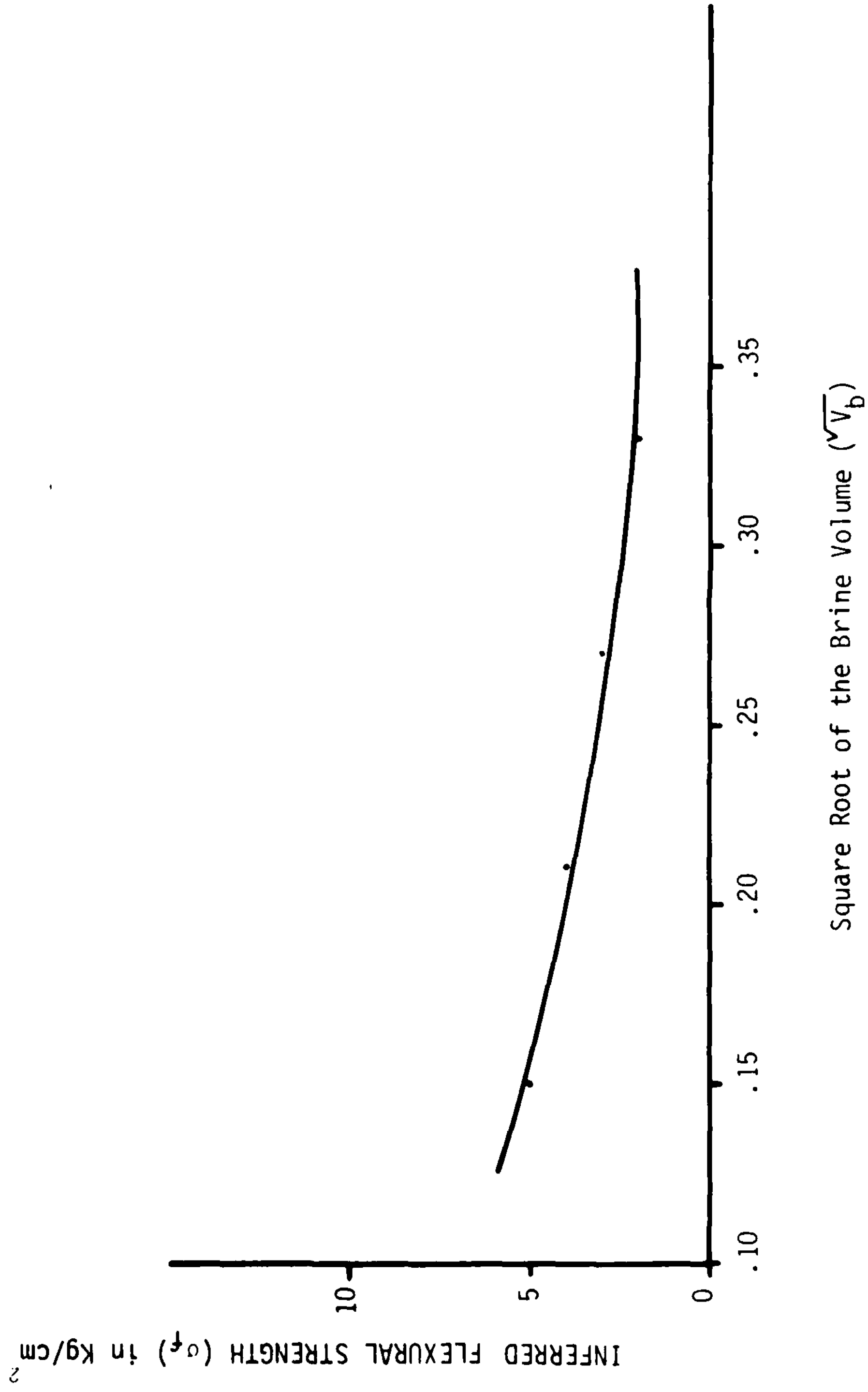
Table 1 RELATIVE BRINE VOLUME

TO GET Vb MULTIPLY VALUE IN TABLE BY OBSERVED SALINITY (0/00).

TEMPERATURE IS "AT COLLECTION TIME".

DATA SHEET 41 (Continued)

(AFTER DATA IN WEEKS AND ASSUR, CRREL, 1967.)



DATA SHEET 41 (Continued)

(AFTER DATA FROM PEYTON IN WEEKS AND ASSUR, CRREL, 1967.)

(temperature 8.7 C)

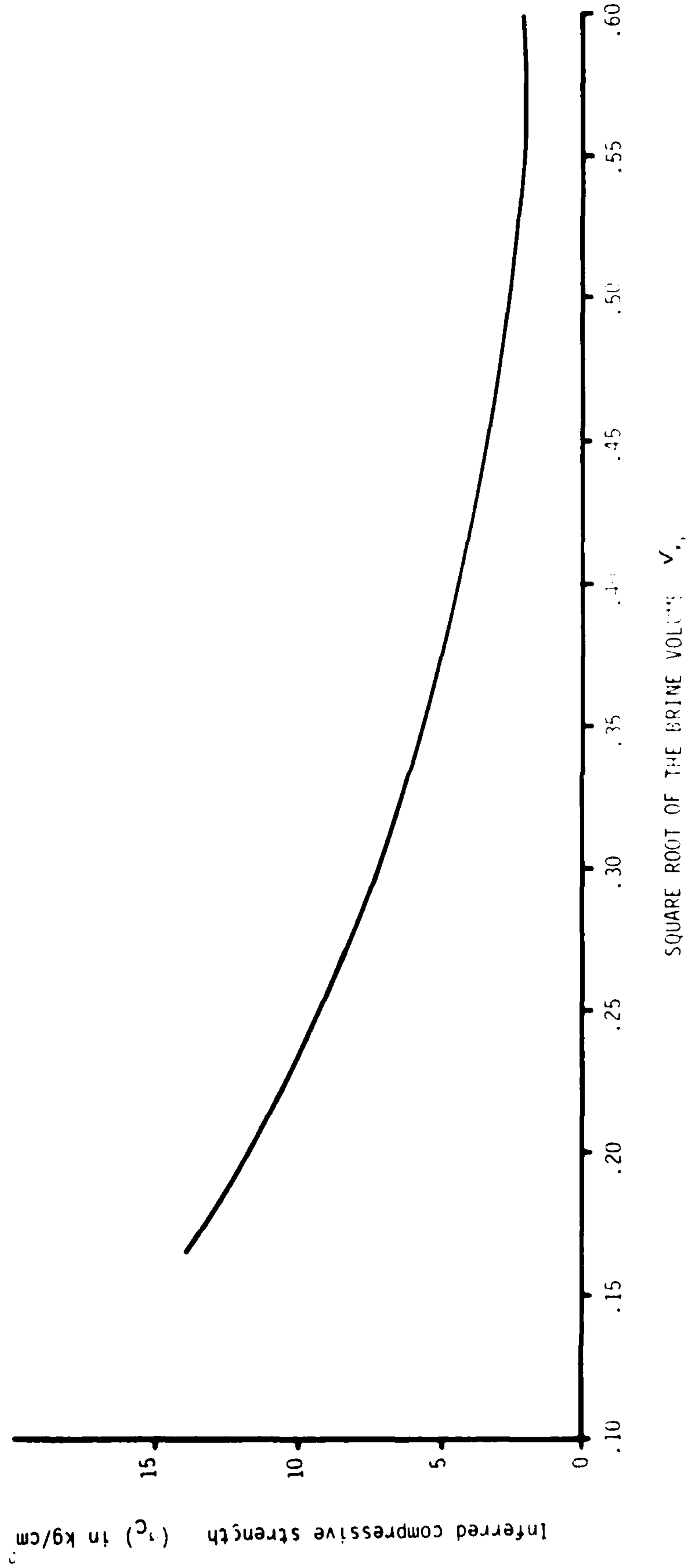
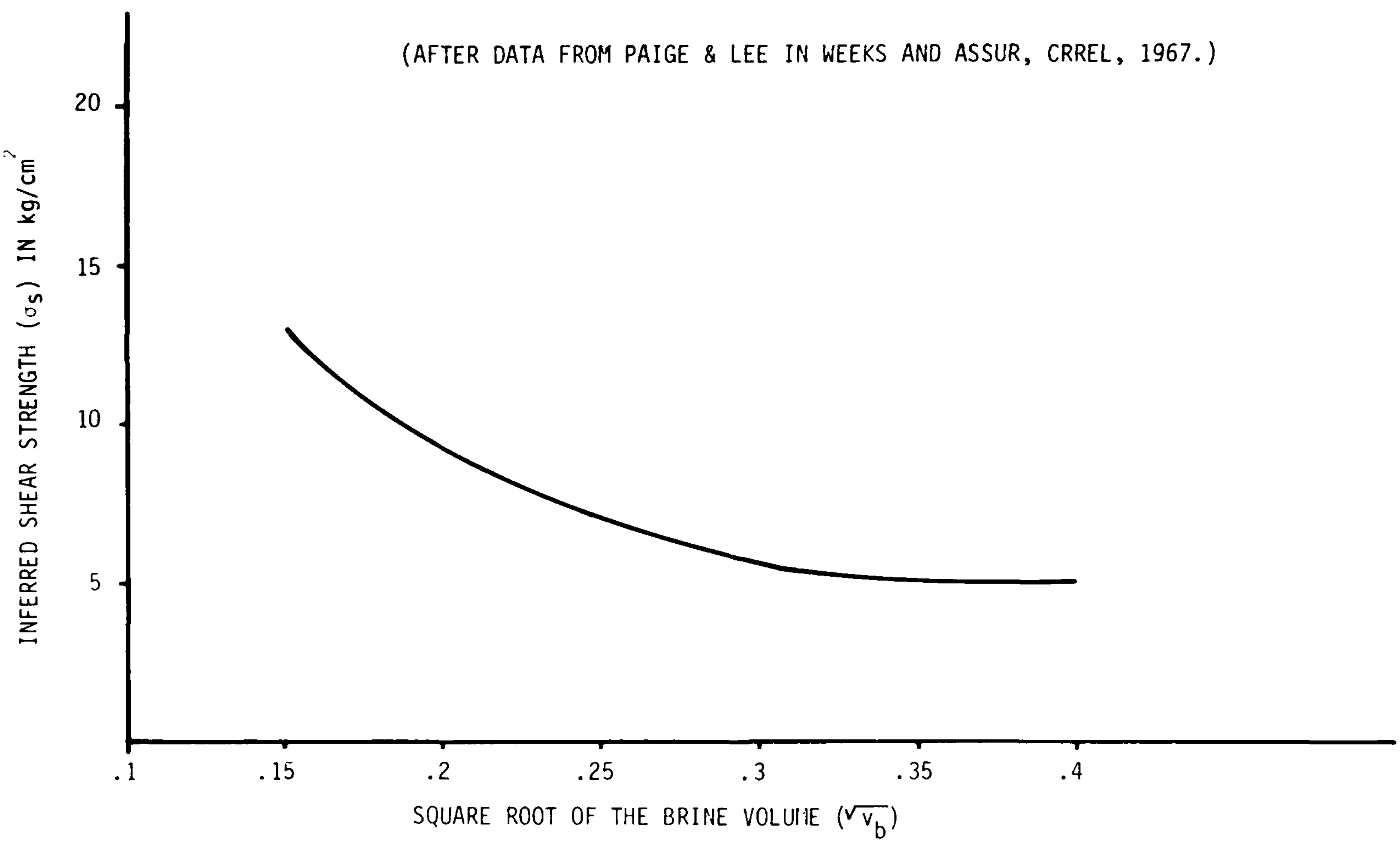


Figure 2 . Inferred compressive strength

Figure 3. Inferred shear strength



AD-A121 527 TEST AND EVALUATION OF CGC POLAR STAR WAGB 10 VOLUME II 3/3
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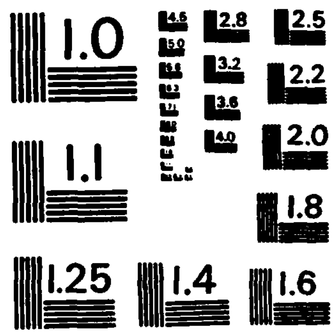


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DATA SHEET 42

PRESSURE RIDGE PROFILE

DATE ____________________

LOCATION ____________________

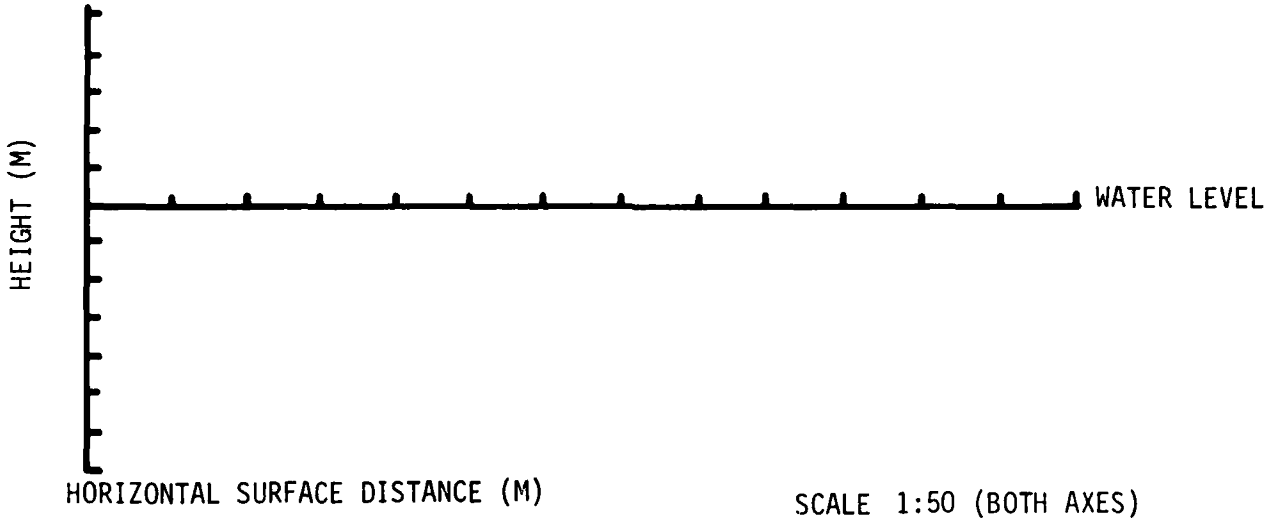
WX: (CIRCLE) CAVU OVC SNOWING

AIR TEMP.__________°C

WIND SPEED_____KTS WIND DIRECTION_____°T

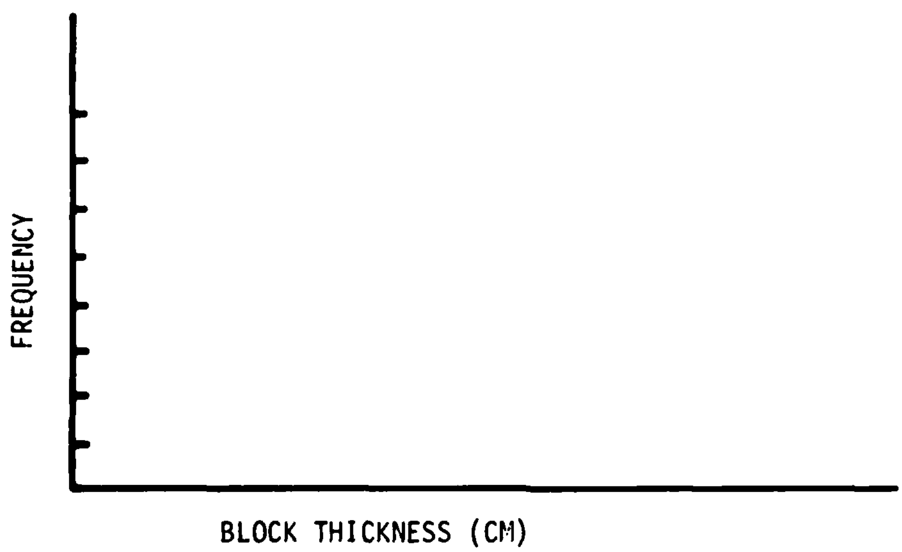
DISTANCE BELOW WATER LEVEL	WATER TEMP C	SURFACE DISTANCE TO RIDGE POSITION	HEIGHT AT PREVIOUS POSITION	THICKNESS OF ICE BLOCKS IN RIDGE	RANGE TO NEAREST OBJECT

DATA SHEET 42 (Continued)



SCALE 1:50 (BOTH AXES)

PRESSURE RIDGE PROFILE



SCALE X AXIS 1:50

HISTOGRAM OF BLOCK THICKNESS

VIII APPENDIX

GLOSSARY OF TERMS

VIII APPENDIX

GLOSSARY OF TERMS

annual ice - see "first year ice."

bare ice - ice without snow cover.

concentration - ratio in eighths of the sea surface covered by ice to the total area of sea surface.

data point - a particular set of measurements obtained under "steady state" conditions.

fast ice - sea ice which forms and remains attached to the coast.

first year ice - sea ice of not more than one winter's growth; thickness varies from 30 cm. to 2 meters.

floe - any relatively flat piece of sea ice 20 meters or more across.

grounded ice - floating ice aground in shoal water.

hummocked ice - sea ice piled haphazardly one piece over another to form an uneven surface.

lead - any fracture or passageway through sea ice which is navigable by surface vessels.

level ice - sea ice which is unaffected by deformation.

multi-year ice - sea ice up to 3 meters or more thick which has survived at least two summer's melt.

pack ice - term used in a wide sense to include any area of sea ice, other than fast ice, no matter what form it takes or how it is disposed.

plate ice - same as level ice (level ice preferred).

pressure ridge - a line or wall of broken ice caused by pressure.

refrozen lead - a lead which contains level ice from wall to wall.

run - a movement or intended movement of the ship to obtain a particular type of data.

sea ice - any form of ice originating from the freezing of sea water.

sheet ice - same as level ice (level ice preferred).

test - an evolution intended to determine a particular item of information.

uniform ice - same as level ice (level ice preferred).

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Report consists of 4 (four) volumes

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Icebreaker	Arctic ice
Ice Testing	Antarctic ice
Ship Test	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

CGC POLAR STAR is the first of a new class of American icebreakers built for and operated by the U.S. Coast Guard. The vessel's design incorporates many new and sophisticated systems not found on earlier icebreakers.

The primary objective of the test and evaluation program was to examine the performance characteristics under actual polar operations. Two field trials were conducted. The first in the Arctic and the second in the Antarctic. During these field trials approximately 120 individual parameters were

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measured and recorded on magnetic tape. Additionally, the physical properties of the sea ice in which the ship was operating were measured.

Documentation of the complete program including preliminary screening of the data has been accomplished by NORDA under contract to the Coast Guard Research and Development Center. The documentation consists of the following four volumes: I. Antarctic Trials, II. Test Plans, III. Background, and IV. Instrumentation Manual.

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